Spill Pathway Analysis:
Trajectory Modeling of the September 1998 Spill in the San Francisco Southern Traffic Lane

Deborah French and Tatsusaburo Isaji

Applied Science Associates
70 Dean Knauss Drive
Narragansett, RI 02882
Voc: 401-789-6224
Fax: 401-789-1932
Email: dfrench@appsci.com

ASA 99-042

November 12, 1999

Table of Contents

1. INTRODUCTION

In support of the natural resource damage assessment (NRDA) for the September 1998 oil spill in the southern traffic lane just south of the entrance to San Francisco Bay, California, trajectory modeling was performed. The objective is to provide an assessment of the pathways of the oil, and thus exposure to surface waters, shorelines, and associated biota.

The spill was first observed on 27 September 1998 and the response began on 28 September 1998. Based on the age and composition of the oil, and its location relative to shipping at the time, it was determined that the oil originated from the *T/V Command*. The *Command* left San Francisco Bay late on 26 September 1998 and traveled south along the southern traffic lane. Thus, in this report, the assumption is made that the spill site was the location of the *Command* in the southern traffic lane at the appropriate time to account for the observations made in the field.

This report describes the data inputs and results of the trajectory modeling. Inputs include winds, currents, other environmental conditions, and specifications of the release (amount, timing, etc.).

2. OVERVIEW OF MODEL ALGORITHMS

The modeling analysis was performed using a model system developed by Applied Science Associates (ASA) called SIMAP (Spill Impact Model Analysis Package). SIMAP includes (1) an oil physical fates model, (2) a hydrodynamics model for simulation of currents, (3) a biological effects model, (4) input tools for oil physical, chemical and toxicological data, (5) input tools for environmental data, (6) tools to grid and enter geographical data, (7) input tools for biological data, (8) a response module to analyze effects of response strategies, (9) graphical visualization tools for outputs, and (10) exporting tools to produce text format output. In this study, only the physical fates and hydrodynamics models were used for simulation of the pathway of the oil.

SIMAP was developed from the oil fates and biological effects submodels in the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME). The NRDAM/CME (Version 2.4, April 1996) was published as part of the CERCLA type A Natural Resource Damage Assessment (NRDA) Final Rule (Federal Register, May 7, 1996, Vol. 61, No. 89, p. 20559-20614). The technical documentation for this model is in French et al. (1996a,b). The model algorithms will only be briefly summarized here.

The physical fates model estimates the distribution of oil (as mass and concentrations) on the water surface, on shorelines, in the water column and in the sediments. The model is three-dimensional, using a latitude-longitude grid for environmental data. Algorithms based on state-of-the-art published research include spreading, evaporation, transport, dispersion, emulsification, entrainment, dissolution, volatilization, partitioning, sedimentation, and degradation. Oil mass is tracked separately for low molecular weight aromatics (1 to 3-ring PAHs) which cause toxicity in the model, other volatiles, and non-volatiles.

SIMAP includes the physical fates model in the NRDAM/CME, with several changes and additions, summarized below. A complete description of the fates model algorithms is in Appendix A of French (1998), while French et al. (1999) contains documentation of the design and sources of the algorithms and data. Most of the additions were made to increase model resolution, allow modification and site-specificity of input data, allow incorporation of temporally-varying two- or three-dimensional current data, and facilitate analysis of results. Thus, most of the additions are to enable changes to the input data (from that provided with the NRDAM/CME) rather than to model algorithms.

Differences between the SIMAP model algorithms and those in the NRDAM/CME are:

- Evaporation algorithm: The NRDAM/CME is based on Mackay et al. (1980) and Payne et al. (1984), while SIMAP uses the empirical formulation in Stiver and Mackay (1984). The results are similar with these two algorithms.
- Entrained oil droplets: In the NRDAM/CME they are assumed to move horizontally with the same surface currents as surface slicks. Surface slicks are transported by tidal and background currents from a current file, plus the added vectors of surface wind drift. In SIMAP, the surface wind drift is only applied to entrained droplets if they are in the surface wind-mixed layer (about 1.5 times wave height). SIMAP tracks entrained droplets separately from surface slicks.
- Sedimentation of entrained oil droplets: This is not included in the NRDAM/CME (which assumes it is zero), but is included in SIMAP.
- Degradation rates: The NRDAM/CME uses two rates, one for water column oil and one for sedimented oil. The rates are in the database. SIMAP uses user input for these rates, and allows different rates for low molecular weight aromatics and whole oil.
- Entrainment: In both models, the same entrainment algorithm Delvigne and Sweeney (1988) is used to simulate mixing of oil into the water by wind-driven waves breaking on the water surface. The NRDAM/CME assumes the spill occurs on the water surface. However, a subsurface release and surf entrainment algorithm has been added to SIMAP, also based on the algorithm and data of Delvigne and Sweeney (1988). The energy and particle size distribution for various assumed levels of turbulence during the release are taken from Delvigne and Sweeney (1988). The subsurface release is initialized by the model in a user-defined volume and location in the water column. The user also sets the turbulence level of the release. Highly turbulent surf entrainment is specified by the user for a window of time after the spill.
- Calculation of water column concentrations: Both models use Lagrangian particles to track the center of mass of sublots of entrained or dissolved oil. Each particle has an inferred Gausian (normal) spatial distribution of mass around it, calculated from the horizontal dispersion (randomized mixing) coefficient and the time since the mass entered the water column. In the NRDAM/CME, when concentrations are calculated,

the mass is assumed evenly distributed out to one standard deviation from the center in the two horizontal directions. In SIMAP, this distribution is truly Gausian (a more accurate representation). In both models, the contributions of mass from all submerged particles is summed into a "plume grid", which is a three-dimensional concentration grid quantifying the concentrations in the water at any given time.

- Dispersion (mixing) coefficients: The NRDAM/CME uses the model of Okubo (1971) to relate the horizontal dispersion coefficient to the length scale of the grids used. Because of the large sizes of the grids in the NRDAM/CME, the horizontal coefficient defaults to a maximum of 100 m^2/sec. The vertical coefficient is assumed 1 cm^2/sec, except in the surface wind-mixed layer (1.5 times wave height), where it is a function of wind speed. SIMAP uses user inputs for the horizontal and vertical coefficients to be used below the wind-mixed layer, and the same surface wind-mixed layer algorithm.
- Numbers of Lagrangian particles: The NRDAM/CME uses default numbers of particles to represent the oil and biota exposed to oil. In SIMAP the user may set these values.

Thus, the fates models are not significantly different in SIMAP and the NRDAM/CME, except as noted above regarding subsurface and surf entrainment, dispersion coefficients, and concentration field calculations. Additional model output formats were also added to SIMAP. Both models in SIMAP may use site-specific data inputs, whereas in the NRDAM/CME, default databases are used. The changes in the databases and model defaults cause the largest changes in the results produced by the two models.

3. INPUT DATA

3.1 Scenario

Figure 3-1 shows the locations of oil slicks observed from 27 September to 1 October 1998. The area is just west of Half Moon Bay. It may be seen that the slicks did not move much during the period, owing to both light winds and slow currents.

Figure 3-2 shows the traffic lanes, the separation zones between inbound and outbound traffic, and the path of the *Command*. The *Command* passed through the area between the turning point southward just outside the bay entrance to the point just west of Half Moon Bay between 2100 and 2200 hours on 26 September 1998.

The spill site was assumed to be along the track line of the *Command* nearest the location of the first observation of the oil the following morning (27 September). The length of the initial release is assumed equal to the length of the elongated slick when it was first mapped on 28 September.

The release apparently occurred at the water surface, based on the consistency (i.e., continuous and fresh black oil) of the observed oil in the following two days. If the release were significantly deep in the water column, the oil would be more broken up into sheens and tar balls. The release was assumed to occur in less than one hour (modeled as instantaneous). The US Coast Guard Marine Safety Office estimated the volume released at 3000 gallons.

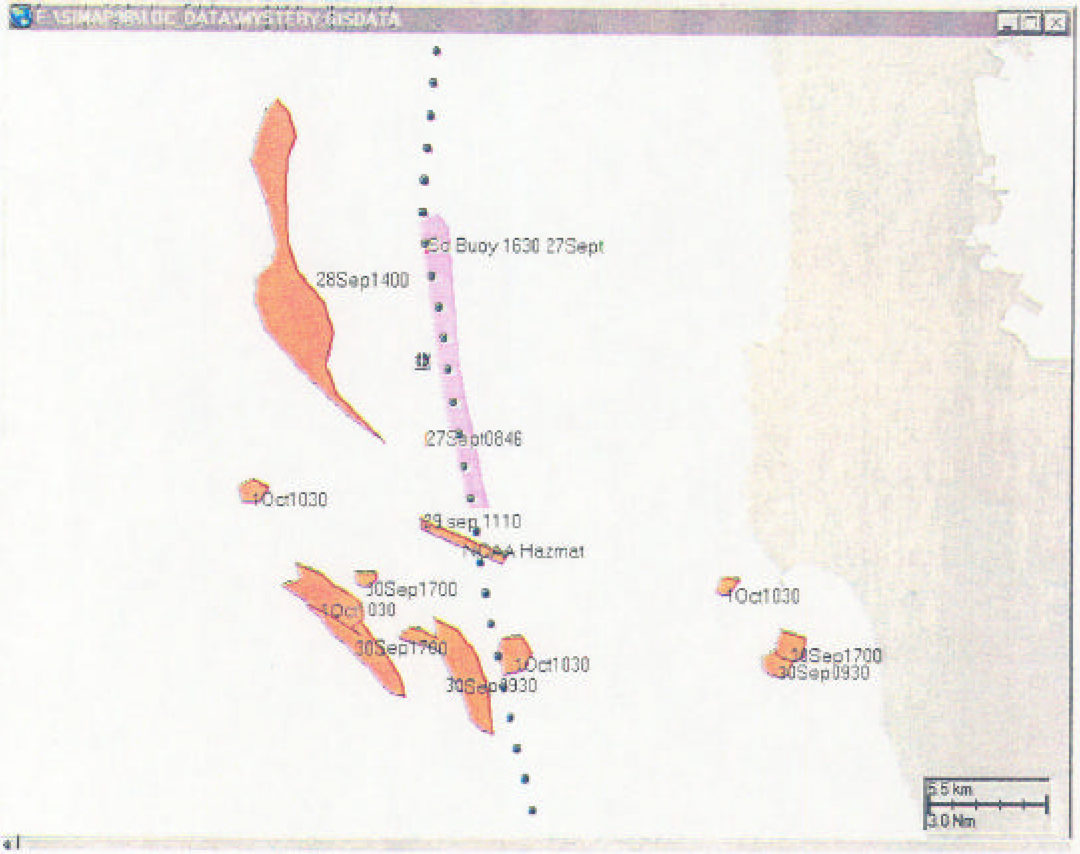


Figure 3-1. Oil slicks observed from 27 September to 1 October, 1998. The dots represent the track line of the Command. The shaded section of the track line is the assumed location of the release.

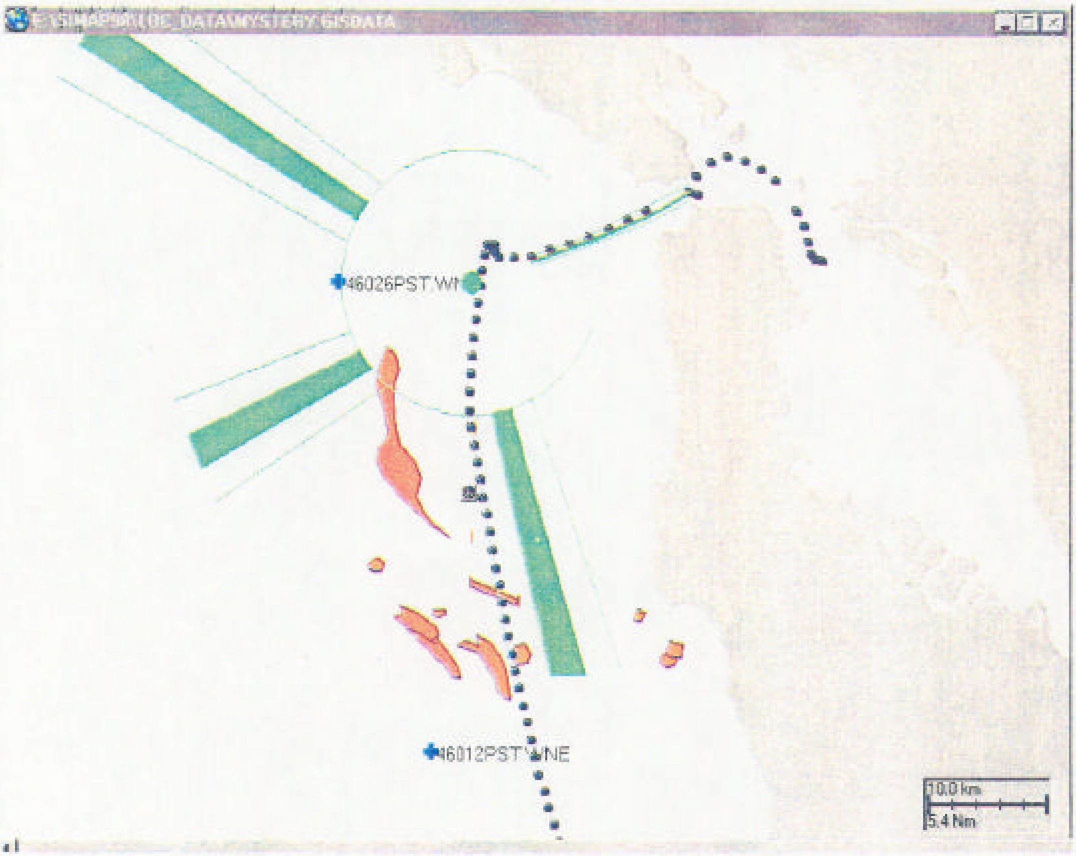


Figure 3-2. Traffic lanes, separation zones between inbound and outbound traffic, and the path of the *Command* as it left San Francisco Bay on 26 September 1998. Oil slick observations from Figure 3-1 are also shown. The NOAA weather buoys (46026 and 46012) are noted.

3.2 Geographical and Model Grid

For geographical reference, SIMAP uses a rectilinear grid to designate the location of the shoreline, the water depth (bathymetry), and the habitat type. Habitat types are intertidal shore types or subtidal categories. The grid is generated from a digital coastline using the ESRI Arc/Info compatible Spatial Analyst program. The cells are then coded for depth and habitat type.

The digital shoreline used was obtained from the State of California (OSPR) GIS database. This is the same data included in the California version of the NRDAM/CME.

Depth data were obtained from Hydrographic Survey Data supplied on CD-ROM by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center. Hydrographic survey data consist of large numbers of individual depth soundings. The depth soundings were gridded using the ESRI Arc/Info compatible Spatial Analyst program.

The model grid is also coded by habitat type. However, for this analysis, since the oil remained primarily offshore, habitat mapping was not performed. The coastline was simply defaulted to sand beach, while the water was defaulted to a sand bottom. This simplification had no influence on the trajectory modeling results.

3.3 Environmental Data

The model uses hourly wind speed and direction for specified locations within the model grid. The model can use multiple wind files, spatially interpolating between them to determine local wind speed and direction.

Two wind data sets for nearby locations are available for September-October 1998. Standard meteorological data were acquired from the National Data Buoy Center Internet site for the NDBC buoys: (1) number 46012, "Half Moon Bay", at 37.39°N, 122.73°W and (2) number 46026, "San Francisco", at 37.75°N, 122.82°W. Hourly mean wind speed and direction for the months of September-October 1998 were compiled in the SIMAP model input file format. Wind speed and direction data are in Appendix A.

Surface water temperature at buoys 46012 and 46026 averaged 14°C during the week after the spill. A mean temperature of 14 °C is assumed for both the water surface and the air immediately above the water. Water temperature affects evaporation rate, and so surface oil volume, but not the trajectory of the spill. The effect of water temperature within the range of a few degrees Celsius is insignificant.

Salinity is assumed 32 ppt, based on French et al. (1996). Salinity has no influence on the model trajectory.

Suspended sediment is assumed 10 mg/l, a typical value for coastal waters. The sedimentation rate is set at 3 m/day. These default values have no significant affect on the model trajectory, so their values are not explored further.

The horizontal diffusion (randomized mixing) coefficient was assumed to be 1 m^2/sec, a typical value for nearshore waters under calm wind conditions, such as occurred during the spill event. The vertical diffusion (randomized mixing) coefficient is assumed 0.001 m^2/sec. These are reasonable values based on Okubo (1971) and modeling experience.

3.4 Currents

Currents have significant influence on the trajectory, and are critical data inputs. Tidal current and locally-force alongshore current data were generated using ASA's hydrodynamic model, as described in detail in the next section.

3.4.1 Hydrodynamic Modeling

3.4.1.1 Oceanographic Setting

Area of interest is located west of San Francisco Bay on a relatively wide (~50km) portion of the north central California continental shelf in the Gulf of the Farallon. The area is bounded loosely by the Farallon Islands to the west, Point Reyes to the north, Point Ano Nuevo to the south and San Francisco Bay to the east. The coastline and bathymetry are generally oriented in a northwest to southeast direction. Water depths where oil slicks were reported are 50 ~ 100 meters. San Francisco Bay lies inside of the narrow entrance of the Golden Gate. Pt. Reyes is one of the most prominent points along the coast and forms sheltered waters to the south. The bathymetry becomes complex near northern shelf break where several canyons, sea mounts and banks exist.

In the past numerous oceanographic research programs have been conducted along the California coast. The majority of programs focused on the large-scale circulation or particular physical processes, and seemed to be of limited use for this specific area. The US Geological Survey and U.S. Army Corps of Engineering sponsored a series of current moorings in 1989 and 1990 (13 months) to study sediment transport patterns in the gulf. The findings were described in detail in Noble and Gelfenbaum (1990) and Sherwood et al (1990). Brief summaries of current measurement analysis are following.

- Tidal currents accounted for approximately 50~70% of variance and higher toward the bay entrance.
- Wind driven flows accounted for 40~50% of variance over the period of 2~10days.
- The mean alongshore component of currents was southward.
- Alongshore currents varied by season, but did not correspond directly the seasonal pattern observed in large-scale California shelf.
- Low-frequency currents were aligned with local bathymetry

This result suggests tidal and wind-driven currents constitute major variable components for short time scales (less than a week). Low frequency alongshore currents were controlled by other large-scale atmospheric and oceanographic conditions.

No actual current measurements exist in the region, for the period of the spill (~26-27 Sep. 1998). Wind observations are available from NOAA's Marine Environmental Buoy Database (see section 3.3). Water elevation observations are also available along the shore where NOAA/NOS tide gages are deployed.

3.4.1.2 Hydrodynamic Model Simulation

We used ASA's numerical hydrodynamic model to generate the applicable hydrodynamic data sets suitable for use in the SIMAP model system. The model's governing equations are described in detail in Isaji and Spaulding (1984, 1987).

The model area included all waters of interest aforementioned including San Francisco Bay (Figure 3-3.) The model region was discretized with 2 km grid cell resolution using bathymetric data mainly from GEODAS (National Geophysical Data Center) and supplemented by navigational chart #5402.

The model was forced with elevations at the open boundaries and wind stress at surface. No river flows (such as from the Sacramento River) were applied. The open boundary elevations were taken from Schwiderski's Global Ocean Tide Data (Schwiderski 1981). Tidal constituents included four semidiurnal (M2, S2, N2, K2) and four diurnal (K1, O1, P1, Q1) species. Wind records from Buoy 46012 were used to supply the surface stress. Wind from Buoy 46026 in effect is virtually the same. The simulation time covered from September 20 to October 10, 1998.

3.4.1.3 Discussion of the Hydrodynamic Model Prediction Results

The hydrodynamic model predictions may be compared to available hydrographic data (surface elevation and current). The only quantitative observed data in the area and at the time of incident are the water elevations obtained by NOAA/NOS along the shoreline.

Figure 3-4 compares simulated and (NOAA) observed water elevations at the bay entrance. It is important that the timing of high and low water match in order to apply this hydrodynamic model data to spill hind-cast predictions. This excellent agreement is due to the fact that the observation point is close to shore where the tidal components dominate the variation. Figure 3-5 shows simulated currents on 25 September 1998, 00:00am, as an example.

Further away from the bay entrance, the relative influence of the tide diminish rapidly and the alongshore components become dominant. The hydrodynamic modeling includes wind stress that drives the local portion of the alongshore currents. However, alongshore currents, which might be driven by other large-scale atmospheric and oceanographic conditions, are not simulated and remain uncertain. Below we discuss their likely significance for the time of incident.

Figure 3-6 shows elevations (Pt. Reyes, San Francisco, Monterey, and model prediction) and alongshore wind speed for Buoy 46012. All values were low-passed filtered at 40 hours to eliminate tidal variation. Measured elevations were further corrected for the atmospheric adjustment (inverse barometer effect). The low-passed elevation is essentially setup/down (i.e., difference) from the mean sea level for a time. This setup/down may represent variation of the alongshore currents. Alongshore currents induce a geostrophic cross-shore pressure gradient. A set down suggests a southward current at the time, and a setup suggests a northward current. In Figure 3-6, northward flows prevail while the elevation lines are above the mean (> zero), and southward flow prevails, if the elevation is less than the mean. Elevation setup/downs will not directly correspond how fast the alongshore current moved.

According to the measured elevations, a northward flow was sustained for 22 September to 1 October, then the current apparently reversed to the south until 7 October. Alongshore wind speed is also shown in Figure 3-6. If these setup/downs were due to solely to local wind stress, the profile of elevation and wind speed lines would match. Significant correlation may be seen for most of the time. However, the model (the unfiltered and non-smoothed line in Figure 3-6) simulated the general trend well, but under-predicted both the northward and southward flows just before and during the spill period (22 September to 1 October). This is because the local wind is not consistent with the actual alongshore currents at the time. (Observe the alongshore wind in Figure 3-6). Thus, the alongshore currents were generated by other forces away from the area.

For the month of September the wind speed had been significantly less than normal, as well as the elevation setup/down. This suggests that the locally forced alongshore currents were also significantly less than normal.

If the simulated currents were used for spill prediction as is, they would under predict oil movement. For this reason, we used the actual observations of the oil slicks as current drifters, i.e., as measurements of current speed and direction. There were also some drifters released by the NOAA HAZMAT responders, which provide additional similar data. (See discussion below).

3.4.2 Surface Wind Drift

Surface wind drift is calculated within the SIMAP fates model, based on hourly wind speed and direction data. Surface wind drift of oil has been observed in the field to be 1-6% of wind speed in a direction 0-30 degrees to the right (in the northern hemisphere) of the down-wind direction (Youssef and Spaulding, 1993). The average values are 3.5% of wind speed and 0 degrees. These values were assumed in the trajectory analysis.

3.4.3 Other Background Currents

In addition to tidal and surface wind drift, there are other current forces of importance in the waters off San Francisco Bay. These include larger scale oceanographic currents and alongshore drift, and currents generated by density gradients in the water. For this particular location and event in September-October 1998, these "other" currents were much more significant than the tidal currents and locally-driven alongshore currents (see above). Thus, the "other" currents, which will be called "background currents" for the rest of this report, and the surface wind drift were so much more important than tidal currents (at the spill site), that the tidal effect cannot be seen in the observed or modeled trajectory.

This trajectory analysis was originally intended to follow a detailed analysis of where the observed oil slicks originated. The hydrodynamic modeling of currents was to include prediction of tidal and other currents. However, when the case against the *Command* reached settlement, only the tidal and locally forced alongshore current modeling had been completed. Thus, predicted background currents for the times of the spill are not available.

Since the pathway analysis herein *makes the assumption* that the *Command* was the source of the oil, the overflight and other observations of the locations of slicks were used to infer the background currents. A current data file was constructed using the movements of the oil slicks, as well as surface drifters released at the time of the spill, as current measurements. The background current field (Figure 3-7) was assumed constant in time over the week following the spill.

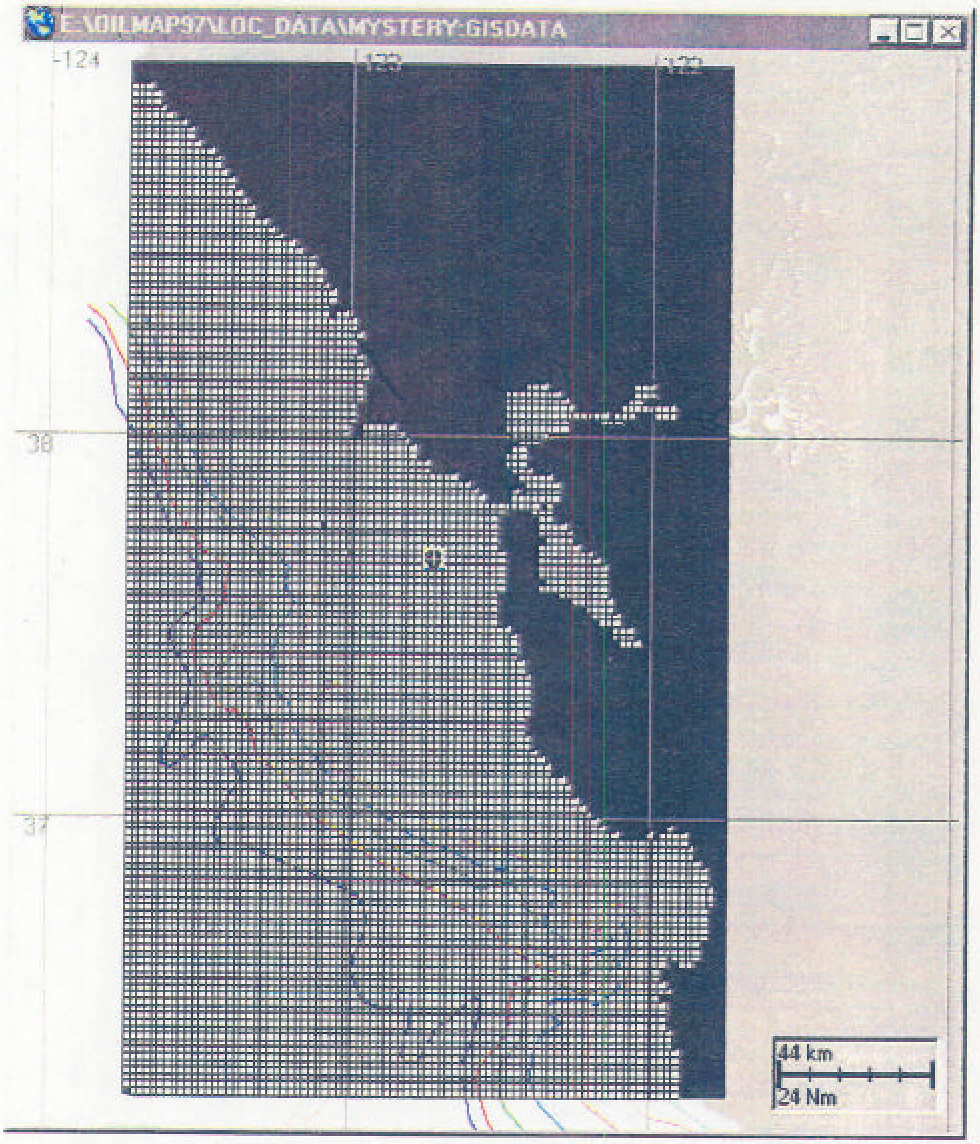


Figure 3-3. Hydrodynamic model grid.

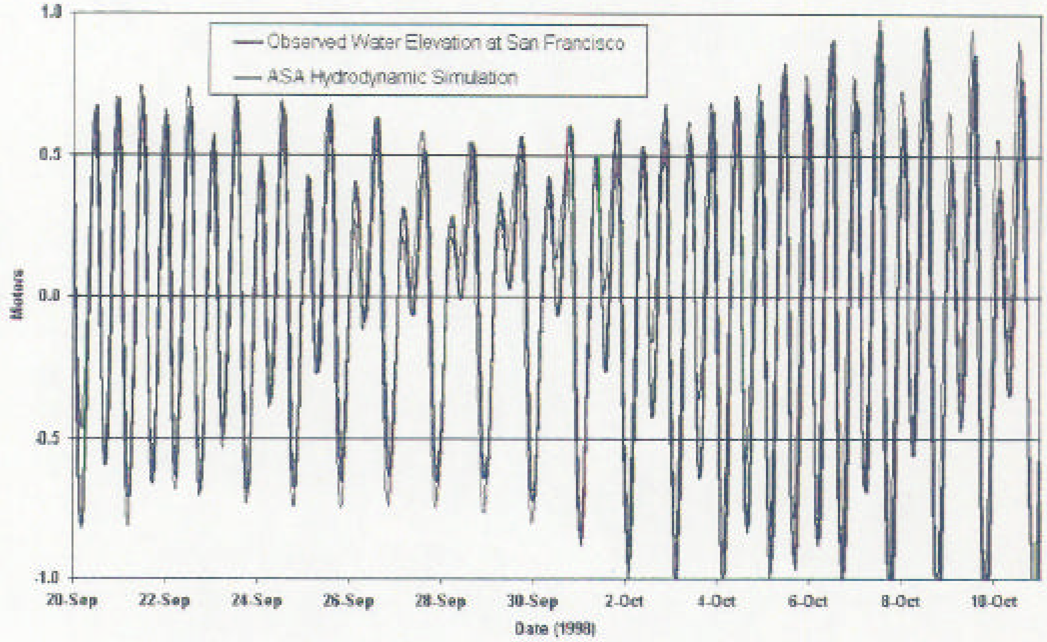


Figure 3-4. Simulated and (NOAA) observed water elevations at the entrance to San Francisco Bay.

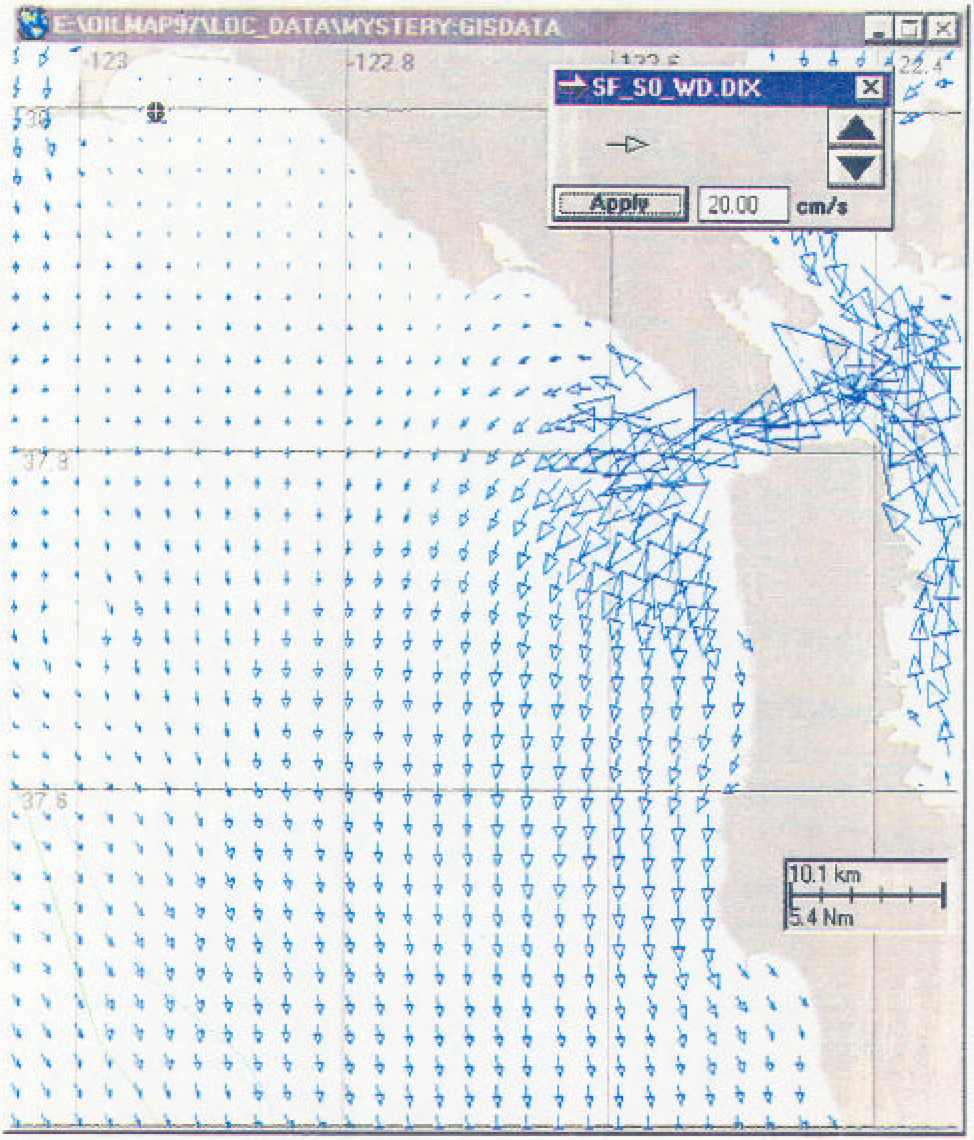


Figure 3-5. Example simulated currents (00:00 25 September 1998)

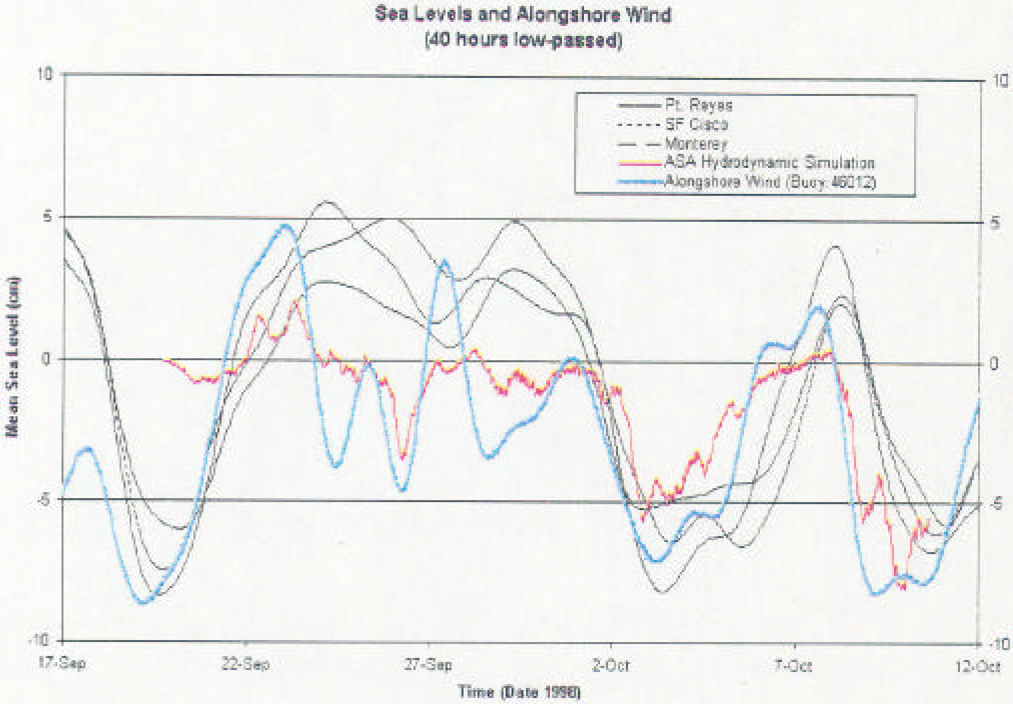


Figure 3-6. Low-passed elevation and alongshore wind.

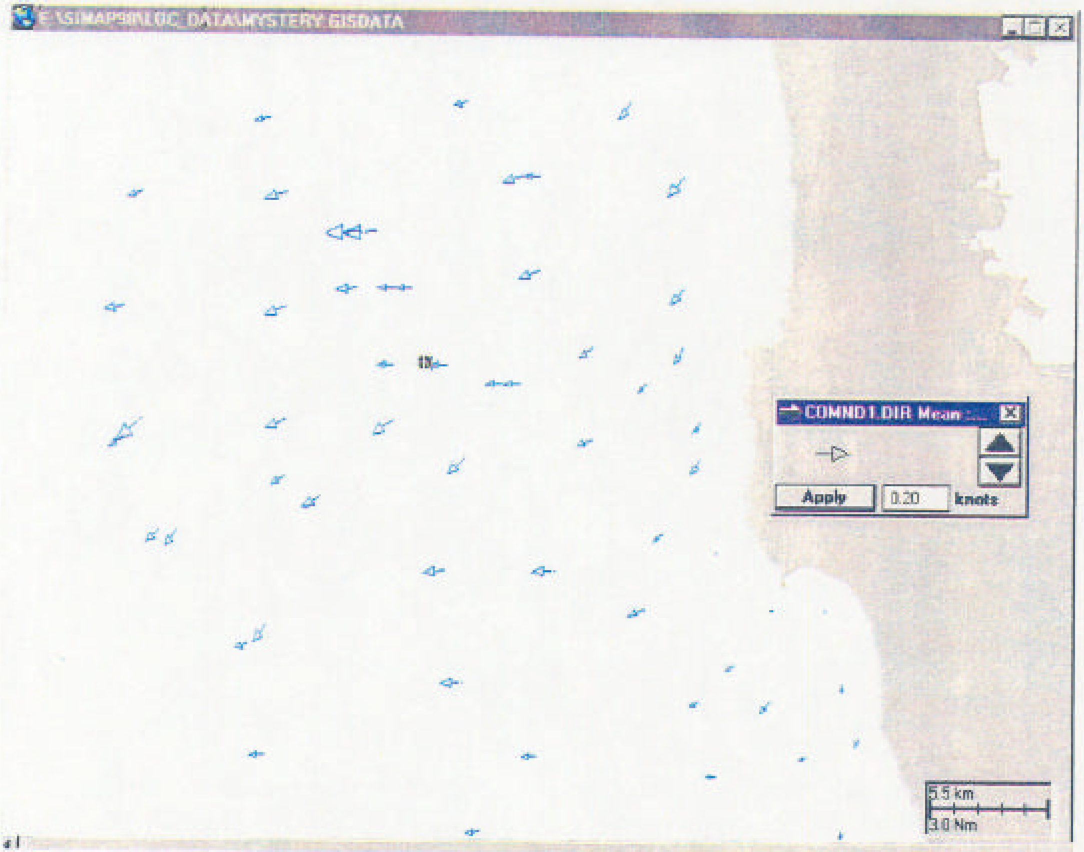


Figure 3-7. Background currents estimated from oil slick movements and drifter buoys.

3.5 Oil Characteristics

The oil observed in the field and on board the *T/V Command* consisted of bunker (No. 6) fuel. Physical and chemical data on No. 6 fuel was taken from the NRDAM/CME database (French et al., 1996b). Constants for the evaporation algorithm were calculated from data obtained from Environment Canada's oil catalog (Whiticar et al., 1992).

For the trajectory analysis, only the percentage of total volatiles has a significant influence on the model results. The volatiles evaporate in the model, decreasing the oil volume over time. The PAH content was assumed 3.1%, an average value. BTEX is assumed negligible, as typical for Bunker fuels. The non-aromatic volatiles are assumed 4.6% (based on Whiticar et al, 1992, from French et al., 1996b).

3.6 Summary of Trajectory Model Inputs

Table 1 and Appendix B contains a list of model inputs for the SIMAP physical fates model. Note that some of the inputs are either not applicable to this case or are not used for the trajectory analysis portion of the model.

Table 1. Inputs for SIMAP Physical Fates Model for the Command Spill Simulation

Name	Description	Units	Common Range of Values	Source(s) of Information	Value(s)
Spill Site	Location of the spill site (verbal or relative description)	(as appro-priate)	(distance from landmark)	U.S. Attorney's Office	Track line of Command 2100-2200 on 26 Sept 1998
Spill Latitude	Latitude of the spill site (accurate to <1 min.)	Deg. N	-90.0 to +90.0	(center of area of release)	37° 35.3618'N
Spill Longitude	Longitude of the spill site (accurate to <1 min.)	Deg. E	-180.0 to +180.0	(center of area of release)	122° 41.4345'N
Depth of release	Depth below the water surface of the release	m	0 (at or above surface) or >0 (for subsurface)	Assumed, based on oil consistency	0 m = Water surface
Start time and date	Date and time the release began	Date, hr,min	-	(based on time Command passed)	26 September 1998 2100
End time of release	Date and time the release ended	Date, hr,min	-	(assumed instan-taneous)	26 September 1998 2100
Total spill volume or mass	Total volume (or weight) released	bbl, gal., MT, kg, m^3	-	USCG MSO	3000 gal.
Timing of release(s)	Timing or rate(s) of release over duration of the spill (see note 1)	(volume per time interval)	Volume, mass or percent	(assumed instan-taneous)	One instan-taneous release
Substance released: name	Oil type	(name)	Name	USCG and on-scene responders	No. 6 fuel
Substance released: density	Density of the oil or chemical released	g/cm^3 or API	0.8-1.1 g/cm^3 or API	Typical value	0.953 g/cm^3
Substance released: viscosity	Viscosity of the oil released	Centi-poise (cp)	100-10000 cp	Typical value	3180 cSt
Substance released:	Fraction of oil which is not	fraction	0-99%	Boiling curve and	4%

non-aromatic volatile fraction	aromatic and with mol.wt. < 200 (boiling points <340°C) (will volatilize)			HC analysis (Whiticar et al, 1992)	
Substance released: BTEX fraction	Fraction of oil which is monoaromatics (BTEX)	fraction	0-10% generally	Typical value	0
Substance released: PAH fraction	Fraction of oil which is 2-3 ring aromatics (PAHs)	fraction	0-10% generally	Typical value	3.1%
Substance released: water fraction	Fraction of spill volume which is water	fraction	0 or more %	(not applicable)	0
Salinity	Surface water salinity	ppt	0-40ppt	French et al. (1996b)	32 ppt
Water Temper-ature	Surface water temperature	Deg.C	0-35°C	NOAA buoys	14°C
Air Temper-ature	Air water temperature at water surface	Deg.C	-10-40°C	NOAA buoys	(assume = water temperature)
Wind data	Hourly wind speed and direction (may use multiple wind stations)	Kts or m/sec, deg.	-	NOAA buoys	NOAA buoys 46012 and 46042
Current data	Current speed and direction as function of time and space	cm/sec by x,y,z,t	-	Hydro-dynamics modeling and inference from slick observations	(see text and figures)
Coastline data	Data set of shoreline locations	Latitude, longi-tude	-	(GIS data)	CA GIS
Shoreline type	Shoreline classification by shore segment	(type by line segment or polygon; GIS data)	(see note 2)	ESI and other mapping; CA GIS data sets	(not incorporated – default of sand beach assumed)

Habitat type	Habitat mapping (shoreline and subtidal)	(type by line segment or polygon; GIS data)	(see note 3)	Shore type and habitat mapping; CA GIS data sets	(not incorporated – default of sand beach or bottom assumed)
Fetch	Fetch = distance to land to N, S, E, W (if landfall not in model domain)	km	>0 km; 1000 km if open ocean	Charts	1000 km to W to open ocean
Wind drift speed	Speed oil moves down wind relative to wind	% of wind speed	1-6% (3.5% ave.)	Literature	3.5%
Wind drift angle	Angle to right of wind (in northern hemisphere) that oil drifts	Deg. To right of down wind	0-30 (0 at middle and low latitudes)	Literature	0
Horizontal dispersion coefficient	Randomized turbulent dispersion parameter in x & y	m^2/sec	0.1-100 about 1 in estuaries 10 in open sea	Literature	1 m^2/sec
Vertical dispersion coefficient	Randomized turbulent dispersion parameter in z	m^2/sec	0.0001-0.001	Literature	0.001 m^2/sec
Suspended sediment concentra-tion	Average suspended sediment concentration during spill period	mg/l	1-50mg/l (10mg/l typical)	Literature	10 mg/l
Suspended sediment settling rate	Net settling rate for suspended sediments	m/day	0.1-3 m/day	Literature	3 m/day

Notes:

1. The model can simulate one or two discrete releases of differing volumes and time periods. There may be an interval of time between the 2 releases. Thus, details of the release timing may be used to define two releases of different amounts and durations.
2. Shore types include: rocky, gravel, sand beach mud flat, wetland (saltmarsh, mangrove), mollusk reef, coral reef, algal bed, seagrass bed, artificial, ice edge). Environmental Sensitivity Index (ESI) data may be mapped to these categories.
3. Habitat types include the shore types listed above, plus subtidal habitats: rock bottom, gravel bottom, sand bottom, silt-mud bottom, algal bed, seagrass bed, coral reef, mollusk reef, and subtidal areas within wetlands)

4. TRAJECTORY MODELING RESULTS

Three trajectory cases were run:
1. Trajectory with the wind drift only
2. Trajectory with the wind drift and the hydrodynamic model-generated currents
3. Trajectory based on wind drift and the inferred currents from the oil slick movements

Model outputs include a considerable amount of data, such as time series maps of surface oil location, area coverage, and thickness (trajectory) and shoreline oiling (amount per length of shore). The model also estimates the water surface area swept by oil.

The output of cases 1 and 2 are visually extremely similar. This is because the modeled currents are very weak relative to the surface wind drift. Both these trajectories show the oil meandering as observed for the first three days (27 September-29 September), but they both incorrectly predict that the oil would all go ashore on 30 September just north of Half Moon Bay. In case 3, the oil is held offshore, as was observed, from 29 September to 2 October. This westward drift is not strong, but is sufficient to keep the oil from beaching in and near Half Moon Bay.

Appendix C contains time series maps of the surface trajectory and shoreline oiling over time. Only the third case, which is the best estimate of the oil spill trajectory, is shown for (relative) brevity. Other model outputs are available upon request, if there is interest.

The modeled trajectory agrees well with the observations. However, the exact locations are not matched precisely. It would take considerable study to simulate the currents precisely and to obtain a perfect match to the observations.

The model estimates that 183.7 km^2 of water surface was swept by slicks during the spill event. The thickness threshold for this calculation was 1 micron. It would be expected that all birds on the surface of the water in this area would be oiled. Note that birds are not on the water surface 100% of the time, but would be present there some percentage of the time. Thus, there is some species-specific probability that a bird would be on the water surface when the slick passed by.

Weighing the area swept by the time that oil was on the surface (i.e., multiplying the area times time present and summing), the sea surface was oiled 7.6 km^2 -days. This infers that the oil remained in a given location on average for 2.5 minutes.

It should be noted that the estimated area swept by oil is not sensitive to the specific location of the slick over time (as long as it remains off the shoreline). Thus, even if the trajectory were perfected to precisely match the observations, the area swept by oil would not be significantly different.

5. CONCLUSIONS

The available data and modeling performed here are entirely consistent with the presumption that the spilled oil came from the *Command*. The likely spill location and time is coincident with the passing of the ship through the area. Because of the weak winds and currents between the presumed time of the release and the first observation of slicks, the oil had moved very little over that period.

The model trajectory fills in the gaps between the overflight observations and completes the picture of the oil's trajectory. The model provides an estimate of area swept by oil, 183.7 km^2, which may be used to quantify injuries to birds in the area and at the time of the spill.

6. REFERENCES

Delvigne, G.A.L. and C.E. Sweeney,1988. Natural dispersion of oil. Oil and Chemical Pollution 4: 281-310.

French, D. P., 1998. Estimate of Injuries to Marine Communities Resulting from the *North Cape* Oil Spill Based on Modeling of Fates and Effects. Report to NOAA Damage Assessment Center, Silver Spring, MD, January 1998.

French, D., M. Reed, K. Jayko, S. Feng, H. Rines, S. Pavignano, T. Isaji, S. Puckett, A. Keller, F. W. French III, D. Gifford, J. McCue, G. Brown, E. MacDonald, J. Quirk, S. Natzke, R. Bishop, M. Welsh, M. Phillips and B.S. Ingram, 1996a. The CERCLA type A natural resource damage assessment model for coastal and marine environments (NRDAM/CME), Technical Documentation, Vol.I - Model Description. Final Report, submitted to the Office of Environmental Policy and Compliance, U.S. Dept.of the Interior, Washington, DC, April, 1996, Contract No. 14-0001-91-C-11.

French, D., M. Reed, S. Feng and S. Pavignano, 1996b. The CERCLA type A natural resource damage assessment model for coastal and marine environments (NRDAM/CME), Technical Documentation, Vol.III - Chemical and Environmental Databases. Final Report , Submitted to the Office of Environmental Policy and Compliance, U.S. Dept. of the Interior, Washington, DC, April, 1996, Contract No. 14-01-0001-91-C-11.

French, D., H. Schuttenberg, and T. Isaji, 1999. Probabilities of Oil Exceeding Thresholds of Concern: Examples from an Evaluation for Florida Power and Light, Proceedings of 22nd Arctic and Marine Oil Spill Program (AMOP) Technical Seminar, Calgary, Alberta, June 1999.

Isaji, T., and M. L. Spaulding, 1984: A model of the tidally induced residual circulation in the Gulf of Maine and Georges Bank. J. Phys. Oceanogr., 14(6), 1119-1126.

Isaji, T., and M. L. Spaulding, 1987: A model of the M2 and K1 tide in the Northern Gulf of Alaska. J. Phys. Oceanogr., 17(5), 698-704.

Mackay, D., S. Paterson and K. Trudel, 1980. A mathematical model of oil spill behavior. Department of Chemical and Applied Chemistry, University of Toronto, Canada.

Muin, M. and M. Spaulding, 1997a. Three-dimensional boundary-fitted circulation model. Journal of Hydraulic Engineering, January 1997, p2-12.

Muin, M. and M. Spaulding, 1997b. Application of three-dimensional boundary-fitted circulation model to the Providence River. J. of Hydraulic Engineering, January 1997, p.13-20.

Noble, M., Gelfenbaum, G., 1990. A pilot study of currents and suspended sediments in the Gulf of the Farallones. USGS, Menlo Park, CA.

Okubo, 1971. Oceanic diffusion diagrams. Deep-Sea Research 8:789-802.

Payne, J.R., B.E. Kirstein, G.D. McNabb, Jr., J.L. Lambach, R. Redding R.E. Jordan, W. Hom, C. deOliveria, G.S. Smith, D.M. Baxter, and R. Gaegel, 1984. Multivariate analysis of petroleum weathering in the marine environment – sub Arctic , Environmental Assessment of the Alaskan Continental Shelf, Final Report of Principal Investigators, Vol. 21, Feb. 1984.

Schwiderski, E. W. 1981. NSWC Global Ocean Tide Data(GOTO 1981) Tape. Naval Surface Weapons Center, Dahlgren, Virginia.

Sherwood, C. R., D. W. Denbo, D. A. Coasts, and J. P. Downing, 1990. Physical Oceanographic Process at Candidate Dredged-Material Disposal Sites B1B and 1M offshore San Francisco, Vol. 1: Analysis and Discussion, prepared for U.S. Army Corps of Engineers – San Francisco District by Pacific Northwest Laboratory, Battelle Memorial Institute.

Spaulding, M.L., D.L. Mendelsohn and J.C. Swanson, 1999. WQMAP: An integrated three-dimensional hydrodynamic and water quality model system for estuarine and coastal applications. Submitted to Marine Technology Society, February 1999.

Stiver, W. and D. Mackay, 1984. Evaporation rate of oil spills of hydrocarbons and petroleum mixtures. Environmental Science and Technology 18: 834-840.

Whiticar, S., M. Bobra, M. Fingas, P. Jokuty, P. Liuzzo, S. Callaghan, F. Ackerman and J. Cao, 1992. A catalogue of crude oil and oil product properties 1992 (edition), Report # EE-144, Environment Canada, Ottawa, Canada.

Youssef, M. and M.L. Spaulding, 1993. Drift current under the action of wind and waves, International Oil Spill Conference, API.

APPENDIX A

Wind Data – Buoy 46026 San Francisco

Year	Month	Day	Hour	Degrees	Knots
1998	9	20	0	308.	20.00
1998	9	20	1	306.	21.60
1998	9	20	2	309.	19.60
1998	9	20	3	311.	20.20
1998	9	20	4	312.	16.80
1998	9	20	5	315.	18.60
1998	9	20	6	319.	14.40
1998	9	20	7	315.	15.00
1998	9	20	8	315.	15.00
1998	9	20	9	309.	10.20
1998	9	20	10	299.	13.20
1998	9	20	11	295.	14.60
1998	9	20	12	290.	15.80
1998	9	20	13	289.	14.20
1998	9	20	14	282.	13.60
1998	9	20	15	284.	13.60
1998	9	20	16	283.	14.20
1998	9	20	17	274.	13.80
1998	9	20	18	274.	11.40
1998	9	20	19	266.	9.40
1998	9	20	20	256.	7.40
1998	9	20	21	246.	7.00
1998	9	20	22	222.	6.00
1998	9	20	23	217.	6.40
1998	9	21	0	280.	7.40
1998	9	21	1	299.	8.00
1998	9	21	2	277.	7.40
1998	9	21	3	257.	8.00
1998	9	21	4	258.	9.40
1998	9	21	5	239.	10.20
1998	9	21	6	278.	10.40
1998	9	21	7	237.	10.40
1998	9	21	8	294.	6.40
1998	9	21	9	278.	6.00
1998	9	21	10	194.	5.00
1998	9	21	11	191.	6.40
1998	9	21	12	177.	6.00
1998	9	21	13	151.	6.60
1998	9	21	15	216.	8.80
1998	9	21	16	222.	7.80
1998	9	21	17	216.	7.20
1998	9	21	18	218.	4.00
1998	9	21	19	99.	1.20
1998	9	21	20	156.	2.20
1998	9	21	21	201.	5.60
1998	9	21	22	169.	4.40
1998	9	21	23	191.	5.80
1998	9	22	0	197.	6.20
1998	9	22	1	192.	3.00

1998	9	22	2	259.	.80
1998	9	22	3	165.	6.20
1998	9	22	4	142.	3.60
1998	9	22	5	145.	3.40
1998	9	22	6	136.	3.60
1998	9	22	7	155.	6.60
1998	9	22	8	143.	7.40
1998	9	22	9	145.	7.00
1998	9	22	10	146.	7.40
1998	9	22	11	154.	7.00
1998	9	22	12	162.	5.60
1998	9	22	13	173.	6.40
1998	9	22	14	186.	6.60
1998	9	22	15	196.	5.60
1998	9	22	16	178.	4.40
1998	9	22	17	184.	6.60
1998	9	22	18	220.	4.40
1998	9	22	20	182.	2.20
1998	9	22	21	97.	2.80
1998	9	22	22	135.	4.60
1998	9	22	23	168.	3.80
1998	9	23	0	133.	1.40
1998	9	23	1	115.	1.80
1998	9	23	2	133.	2.20
1998	9	23	3	94.	2.20
1998	9	23	4	91.	3.00
1998	9	23	5	89.	2.20
1998	9	23	6	57.	2.20
1998	9	23	7	34.	4.20
1998	9	23	8	55.	4.40
1998	9	23	9	73.	4.00
1998	9	23	10	38.	5.80
1998	9	23	11	81.	4.00
1998	9	23	12	159.	5.40
1998	9	23	13	178.	5.00
1998	9	23	14	309.	1.80
1998	9	23	15	305.	1.20
1998	9	23	16	276.	.80
1998	9	23	17	156.	2.80
1998	9	23	18	149.	1.80
1998	9	23	19	330.	6.80
1998	9	23	20	325.	8.20
1998	9	23	21	322.	6.20
1998	9	23	22	296.	4.80
1998	9	23	23	287.	6.60
1998	9	24	0	299.	9.00
1998	9	24	1	313.	10.00
1998	9	24	2	308.	11.60
1998	9	24	3	308.	13.20
1998	9	24	4	306.	13.00
1998	9	24	6	296.	10.40
1998	9	24	7	283.	8.20
1998	9	24	8	284.	6.40
1998	9	24	9	290.	6.20
1998	9	24	10	263.	3.80
1998	9	24	11	229.	5.00
1998	9	24	12	229.	6.00

1998	9	24	13	276.	6.80
1998	9	24	14	253.	8.20
1998	9	24	15	267.	9.20
1998	9	24	16	283.	10.20
1998	9	24	17	271.	7.80
1998	9	24	18	265.	9.20
1998	9	24	19	285.	11.20
1998	9	24	20	286.	12.40
1998	9	24	21	286.	13.20
1998	9	24	22	283.	12.00
1998	9	24	23	277.	10.40
1998	9	25	0	275.	11.80
1998	9	25	1	289.	10.00
1998	9	25	2	278.	9.00
1998	9	25	3	284.	9.40
1998	9	25	4	271.	9.20
1998	9	25	5	280.	10.60
1998	9	25	6	272.	6.80
1998	9	25	7	215.	5.20
1998	9	25	8	235.	8.60
1998	9	25	9	218.	9.20
1998	9	25	10	201.	11.20
1998	9	25	11	183.	13.60
1998	9	25	12	175.	13.00
1998	9	25	13	241.	7.40
1998	9	25	14	271.	6.80
1998	9	25	15	264.	6.80
1998	9	25	16	266.	8.80
1998	9	25	17	286.	8.20
1998	9	25	18	295.	9.00
1998	9	25	19	289.	11.60
1998	9	25	20	296.	14.00
1998	9	25	21	281.	16.60
1998	9	25	22	278.	18.00
1998	9	25	23	268.	14.80
1998	9	26	0	276.	14.00
1998	9	26	1	282.	14.00
1998	9	26	2	264.	13.40
1998	9	26	3	271.	16.00
1998	9	26	4	281.	20.20
1998	9	26	5	276.	18.00
1998	9	26	6	280.	19.20
1998	9	26	7	284.	21.00
1998	9	26	8	292.	18.20
1998	9	26	9	291.	19.20
1998	9	26	10	295.	17.00
1998	9	26	11	294.	18.00
1998	9	26	12	302.	15.40
1998	9	26	13	296.	15.80
1998	9	26	14	303.	14.20
1998	9	26	15	301.	12.80
1998	9	26	16	303.	8.80
1998	9	26	17	355.	2.60
1998	9	26	18	180.	5.20
1998	9	26	19	187.	4.40
1998	9	26	20	257.	2.80
1998	9	26	21	117.	1.20

1998	9	26	22	140.	3.00
1998	9	26	23	163.	1.60
1998	9	27	0	145.	2.40
1998	9	27	1	138.	6.20
1998	9	27	2	160.	6.80
1998	9	27	3	158.	9.80
1998	9	27	4	151.	9.60
1998	9	27	5	161.	8.00
1998	9	27	6	166.	8.20
1998	9	27	7	164.	7.20
1998	9	27	8	149.	9.80
1998	9	27	9	148.	9.20
1998	9	27	10	147.	10.20
1998	9	27	11	145.	8.20
1998	9	27	12	149.	6.60
1998	9	27	13	138.	5.00
1998	9	27	14	140.	4.40
1998	9	27	15	159.	4.40
1998	9	27	16	135.	4.80
1998	9	27	17	149.	2.60
1998	9	27	18	113.	1.80
1998	9	27	19	32.	4.60
1998	9	27	20	358.	2.00
1998	9	27	21	340.	2.40
1998	9	27	22	261.	.60
1998	9	27	23	270.	3.00
1998	9	28	0	272.	1.80
1998	9	28	1	352.	2.60
1998	9	28	2	312.	3.40
1998	9	28	3	357.	3.40
1998	9	28	4	355.	4.40
1998	9	28	5	341.	5.40
1998	9	28	6	342.	4.20
1998	9	28	7	329.	5.40
1998	9	28	8	352.	4.00
1998	9	28	9	76.	1.60
1998	9	28	10	172.	.60
1998	9	28	11	232.	6.40
1998	9	28	12	292.	8.20
1998	9	28	13	288.	9.20
1998	9	28	14	294.	11.00
1998	9	28	15	301.	10.40
1998	9	28	16	296.	12.20
1998	9	28	17	305.	10.60
1998	9	28	18	297.	10.40
1998	9	28	19	299.	10.60
1998	9	28	20	309.	11.40
1998	9	28	21	305.	14.20
1998	9	28	22	303.	15.20
1998	9	28	23	296.	17.60
1998	9	29	0	299.	17.60
1998	9	29	1	306.	18.40
1998	9	29	2	288.	18.40
1998	9	29	3	308.	16.60
1998	9	29	4	293.	17.40
1998	9	29	5	297.	13.60
1998	9	29	6	291.	13.00

1998	9	29	7	298.	12.00
1998	9	29	8	278.	8.00
1998	9	29	9	281.	6.20
1998	9	29	10	279.	5.00
1998	9	29	11	270.	7.40
1998	9	29	12	260.	5.20
1998	9	29	13	250.	5.80
1998	9	29	14	249.	5.20
1998	9	29	15	268.	6.20
1998	9	29	16	258.	9.00
1998	9	29	17	272.	7.60
1998	9	29	18	275.	8.80
1998	9	29	19	271.	9.40
1998	9	29	20	289.	8.40
1998	9	29	21	286.	9.00
1998	9	29	22	278.	8.80
1998	9	29	23	285.	8.40
1998	9	30	0	312.	8.00
1998	9	30	1	297.	6.00
1998	9	30	2	295.	7.40
1998	9	30	3	280.	8.00
1998	9	30	4	311.	8.80
1998	9	30	5	335.	4.40
1998	9	30	6	326.	5.00
1998	9	30	7	298.	6.00
1998	9	30	8	265.	5.80
1998	9	30	9	311.	4.80
1998	9	30	10	13.	2.60
1998	9	30	11	128.	1.20
1998	9	30	12	201.	3.80
1998	9	30	13	225.	3.80
1998	9	30	14	235.	3.40
1998	9	30	15	264.	4.00
1998	9	30	16	273.	2.80
1998	9	30	17	255.	3.80
1998	9	30	18	222.	3.40
1998	9	30	19	245.	5.80
1998	9	30	20	257.	7.80
1998	9	30	21	229.	6.40
1998	9	30	22	247.	6.40
1998	9	30	23	237.	8.20
1998	10	1	0	246.	5.20
1998	10	1	1	240.	6.00
1998	10	1	2	251.	6.00
1998	10	1	3	252.	5.00
1998	10	1	4	266.	6.60
1998	10	1	5	229.	5.20
1998	10	1	6	253.	4.60
1998	10	1	7	219.	5.40
1998	10	1	8	257.	4.40
1998	10	1	9	252.	5.60
1998	10	1	10	269.	5.00
1998	10	1	11	285.	5.00
1998	10	1	12	267.	3.60
1998	10	1	13	312.	2.40
1998	10	1	14	279.	5.20
1998	10	1	15	260.	6.60

1998	10	1	16	284.	9.60
1998	10	1	17	284.	13.20
1998	10	1	18	298.	15.20
1998	10	1	19	278.	16.00
1998	10	1	20	280.	17.80
1998	10	1	21	283.	17.40
1998	10	1	22	286.	15.60
1998	10	1	23	281.	14.80
1998	10	2	0	275.	13.40
1998	10	2	1	274.	12.20
1998	10	2	2	285.	11.60
1998	10	2	3	286.	11.00
1998	10	2	4	275.	5.60
1998	10	2	5	276.	3.20
1998	10	2	6	196.	2.20
1998	10	2	7	283.	11.60
1998	10	2	8	281.	12.40
1998	10	2	9	301.	15.80
1998	10	2	10	286.	17.20
1998	10	2	11	291.	15.60
1998	10	2	12	290.	17.20
1998	10	2	13	294.	18.80
1998	10	2	14	294.	19.60
1998	10	2	15	296.	20.40
1998	10	2	16	294.	21.60
1998	10	2	17	289.	21.20
1998	10	2	18	291.	22.60
1998	10	2	19	290.	23.00
1998	10	2	20	294.	25.80
1998	10	2	21	295.	24.80
1998	10	2	22	296.	21.60
1998	10	2	23	297.	21.00
1998	10	3	0	293.	21.80
1998	10	3	1	293.	21.00
1998	10	3	2	291.	21.40
1998	10	3	3	295.	19.00
1998	10	3	4	293.	19.80
1998	10	3	5	289.	19.20
1998	10	3	6	291.	17.20
1998	10	3	7	291.	18.60
1998	10	3	8	292.	16.80
1998	10	3	9	289.	19.00
1998	10	3	10	283.	19.40
1998	10	3	11	286.	18.40
1998	10	3	12	286.	18.40
1998	10	3	13	283.	19.80
1998	10	3	14	285.	18.80
1998	10	3	15	288.	18.20
1998	10	3	16	293.	16.80
1998	10	3	17	300.	13.80
1998	10	3	18	300.	14.60
1998	10	3	19	302.	13.80
1998	10	3	20	301.	18.80
1998	10	3	21	309.	19.20
1998	10	3	22	298.	18.60
1998	10	3	23	310.	12.60
1998	10	4	0	308.	13.40

1998	10	4	1	311.	12.20
1998	10	4	2	316.	11.00
1998	10	4	3	309.	11.80
1998	10	4	4	312.	14.20
1998	10	4	5	318.	12.40
1998	10	4	6	334.	10.00
1998	10	4	7	336.	9.80
1998	10	4	8	318.	10.60
1998	10	4	9	331.	9.20
1998	10	4	10	313.	8.60
1998	10	4	11	305.	12.40
1998	10	4	12	302.	12.20
1998	10	4	13	305.	11.40
1998	10	4	14	299.	15.20
1998	10	4	15	304.	15.40
1998	10	4	16	308.	15.00
1998	10	4	17	303.	15.80
1998	10	4	18	303.	14.00
1998	10	4	19	300.	13.60
1998	10	4	20	311.	10.40
1998	10	4	21	301.	13.00
1998	10	4	22	326.	8.40
1998	10	4	23	315.	7.00
1998	10	5	0	305.	10.60
1998	10	5	1	306.	10.40
1998	10	5	2	307.	14.80
1998	10	5	3	302.	10.40
1998	10	5	4	309.	10.60
1998	10	5	5	318.	6.80
1998	10	5	6	320.	8.20
1998	10	5	7	347.	6.20
1998	10	5	8	319.	6.80
1998	10	5	9	56.	1.80
1998	10	5	10	292.	5.00
1998	10	5	11	158.	2.80
1998	10	5	12	242.	5.60
1998	10	5	13	193.	3.80
1998	10	5	14	294.	6.60
1998	10	5	15	308.	9.20
1998	10	5	16	312.	10.60
1998	10	5	17	319.	5.20
1998	10	5	18	313.	8.80
1998	10	5	19	308.	8.00
1998	10	5	20	328.	10.20
1998	10	5	21	340.	6.20
1998	10	5	22	333.	4.80
1998	10	5	23	14.	4.60
1998	10	6	0	49.	3.80
1998	10	6	1	112.	6.00
1998	10	6	2	108.	6.00
1998	10	6	3	95.	7.60
1998	10	6	4	94.	7.00
1998	10	6	5	87.	10.60
1998	10	6	6	79.	12.40
1998	10	6	7	79.	12.80
1998	10	6	9	123.	8.20
1998	10	6	10	122.	4.80

1998	10	6	11	126.	4.80
1998	10	6	12	156.	7.40
1998	10	6	13	130.	3.80
1998	10	6	14	150.	5.20
1998	10	6	15	176.	3.40
1998	10	6	16	203.	2.00
1998	10	6	17	257.	2.40
1998	10	6	18	50.	4.60
1998	10	6	19	102.	6.20
1998	10	6	20	212.	8.60
1998	10	6	21	234.	9.80
1998	10	6	22	265.	4.40
1998	10	6	23	240.	9.80
1998	10	7	0	256.	3.60
1998	10	7	1	131.	1.40
1998	10	7	2	136.	6.00
1998	10	7	3	175.	4.60
1998	10	7	4	185.	3.80
1998	10	7	5	115.	2.00
1998	10	7	6	168.	1.20
1998	10	7	7	100.	3.20
1998	10	7	8	94.	4.40
1998	10	7	9	84.	4.60
1998	10	7	10	77.	5.00
1998	10	7	11	128.	5.40
1998	10	7	12	192.	3.40
1998	10	7	13	149.	3.00
1998	10	7	14	232.	2.20
1998	10	7	15	198.	2.20
1998	10	7	16	183.	4.00
1998	10	7	17	150.	4.80
1998	10	7	18	145.	4.00
1998	10	7	19	170.	3.80
1998	10	7	20	182.	4.20
1998	10	7	21	169.	5.20
1998	10	7	22	185.	4.60
1998	10	7	23	219.	5.20
1998	10	8	0	170.	2.40
1998	10	8	1	159.	3.80
1998	10	8	2	153.	4.60
1998	10	8	3	164.	6.60
1998	10	8	4	143.	4.80
1998	10	8	5	234.	.60
1998	10	8	6	291.	7.40
1998	10	8	7	294.	10.20
1998	10	8	8	309.	9.20
1998	10	8	9	306.	9.60
1998	10	8	10	295.	11.60
1998	10	8	11	305.	15.40
1998	10	8	12	305.	14.20
1998	10	8	13	298.	15.00
1998	10	8	14	304.	12.80
1998	10	8	15	301.	15.80
1998	10	8	16	305.	15.60
1998	10	8	17	290.	20.80
1998	10	8	18	297.	18.60
1998	10	8	19	305.	18.20

1998	10	8	20	304.	20.80
1998	10	8	21	302.	20.20
1998	10	8	22	299.	20.00
1998	10	8	23	303.	19.40
1998	10	9	0	304.	18.60
1998	10	9	1	309.	19.00
1998	10	9	2	306.	18.80
1998	10	9	3	302.	17.00
1998	10	9	4	308.	18.40
1998	10	9	5	315.	16.80
1998	10	9	6	305.	18.40
1998	10	9	7	299.	17.20
1998	10	9	8	306.	15.80
1998	10	9	9	297.	18.80
1998	10	9	10	298.	17.20
1998	10	9	11	290.	16.40
1998	10	9	12	283.	18.20
1998	10	9	13	283.	18.60
1998	10	9	14	283.	18.00
1998	10	9	15	287.	20.20
1998	10	9	16	288.	18.00
1998	10	9	17	292.	20.40
1998	10	9	18	297.	23.00
1998	10	9	19	298.	24.40
1998	10	9	20	304.	21.80
1998	10	9	21	301.	23.40
1998	10	9	22	301.	23.60
1998	10	9	23	303.	24.20
1998	10	10	0	306.	23.20
1998	10	10	1	302.	24.80
1998	10	10	2	303.	21.60
1998	10	10	3	304.	20.20
1998	10	10	4	307.	19.00
1998	10	10	5	311.	19.00
1998	10	10	6	310.	16.20
1998	10	10	7	313.	15.20
1998	10	10	8	313.	12.20
1998	10	10	9	320.	10.20
1998	10	10	10	314.	9.40
1998	10	10	11	317.	9.20
1998	10	10	12	317.	12.60
1998	10	10	13	308.	16.00
1998	10	10	14	296.	18.20
1998	10	10	15	303.	17.80
1998	10	10	16	305.	17.60
1998	10	10	17	298.	17.80
1998	10	10	18	300.	16.40
1998	10	10	19	306.	13.80
1998	10	10	20	305.	15.80
1998	10	10	21	304.	13.80
1998	10	10	22	299.	14.00
1998	10	10	23	300.	14.80

Wind Data – Buoy 46012 Half Moon Bay

Year	Month	Day	Hour	Degrees	Knots
1998	9	20	0	318.	18.20
1998	9	20	1	317.	20.20
1998	9	20	2	320.	18.00
1998	9	20	3	320.	18.60
1998	9	20	4	321.	18.00
1998	9	20	5	319.	16.40
1998	9	20	6	312.	16.80
1998	9	20	7	321.	18.00
1998	9	20	8	314.	14.80
1998	9	20	9	302.	15.20
1998	9	20	10	299.	12.80
1998	9	20	11	303.	14.20
1998	9	20	12	296.	13.80
1998	9	20	13	302.	13.00
1998	9	20	14	298.	11.80
1998	9	20	15	292.	13.00
1998	9	20	16	296.	13.00
1998	9	20	17	291.	11.00
1998	9	20	18	279.	10.40
1998	9	20	19	282.	9.20
1998	9	20	20	286.	8.40
1998	9	20	21	292.	8.60
1998	9	20	22	296.	7.20
1998	9	20	23	296.	7.80
1998	9	21	0	287.	7.00
1998	9	21	2	304.	6.80
1998	9	21	3	287.	8.60
1998	9	21	4	286.	7.60
1998	9	21	5	276.	8.00
1998	9	21	6	291.	6.80
1998	9	21	7	282.	5.80
1998	9	21	8	278.	4.00
1998	9	21	9	285.	5.20
1998	9	21	10	258.	2.60
1998	9	21	11	287.	.40
1998	9	21	12	148.	4.20
1998	9	21	13	185.	2.80
1998	9	21	14	202.	3.40
1998	9	21	15	207.	4.60
1998	9	21	16	214.	5.40
1998	9	21	17	234.	5.60
1998	9	21	18	271.	4.20
1998	9	21	19	240.	2.80
1998	9	21	20	204.	3.00
1998	9	21	21	188.	3.80
1998	9	21	22	197.	5.00
1998	9	21	23	170.	4.80
1998	9	22	0	184.	3.20
1998	9	22	1	153.	5.60
1998	9	22	2	174.	7.40
1998	9	22	3	156.	8.60

1998	9	22	4	154.	7.40
1998	9	22	5	138.	8.40
1998	9	22	6	132.	10.20
1998	9	22	7	134.	10.20
1998	9	22	8	124.	11.80
1998	9	22	9	132.	12.60
1998	9	22	10	132.	11.40
1998	9	22	11	136.	13.20
1998	9	22	12	135.	12.40
1998	9	22	13	141.	11.80
1998	9	22	14	146.	11.80
1998	9	22	15	155.	11.80
1998	9	22	16	164.	9.20
1998	9	22	17	148.	7.00
1998	9	22	18	156.	7.20
1998	9	22	19	152.	5.80
1998	9	22	20	177.	4.80
1998	9	22	21	170.	5.40
1998	9	22	22	145.	5.60
1998	9	22	23	136.	5.80
1998	9	23	0	140.	6.80
1998	9	23	1	135.	6.80
1998	9	23	2	128.	7.60
1998	9	23	3	99.	7.00
1998	9	23	4	115.	6.40
1998	9	23	5	115.	7.00
1998	9	23	6	141.	8.60
1998	9	23	7	131.	8.80
1998	9	23	8	131.	10.60
1998	9	23	9	126.	12.40
1998	9	23	10	129.	12.40
1998	9	23	11	131.	11.80
1998	9	23	12	152.	12.00
1998	9	23	13	152.	10.60
1998	9	23	14	164.	9.60
1998	9	23	15	162.	11.60
1998	9	23	16	153.	7.00
1998	9	23	17	161.	6.80
1998	9	23	18	180.	1.00
1998	9	23	19	35.	1.20
1998	9	23	20	57.	2.40
1998	9	23	21	76.	2.20
1998	9	23	22	166.	.20
1998	9	23	23	346.	7.60
1998	9	24	0	335.	6.80
1998	9	24	1	344.	5.00
1998	9	24	2	322.	7.00
1998	9	24	3	315.	10.20
1998	9	24	4	318.	11.60
1998	9	24	5	315.	11.20
1998	9	24	6	320.	10.00
1998	9	24	7	293.	8.40
1998	9	24	8	291.	6.20
1998	9	24	9	293.	7.20
1998	9	24	10	298.	5.60
1998	9	24	11	302.	3.80
1998	9	24	12	296.	3.00

1998	9	24	13	277.	1.40
1998	9	24	14	287.	7.20
1998	9	24	15	278.	8.80
1998	9	24	16	294.	11.20
1998	9	24	17	304.	9.20
1998	9	24	18	295.	7.40
1998	9	24	19	297.	8.60
1998	9	24	20	296.	8.80
1998	9	24	21	288.	10.80
1998	9	24	22	299.	10.20
1998	9	24	23	282.	7.60
1998	9	25	1	281.	7.20
1998	9	25	2	291.	10.80
1998	9	25	3	278.	9.00
1998	9	25	4	284.	10.80
1998	9	25	5	290.	9.40
1998	9	25	6	291.	10.00
1998	9	25	7	267.	8.80
1998	9	25	8	234.	3.40
1998	9	25	9	229.	5.60
1998	9	25	10	208.	7.40
1998	9	25	11	203.	10.00
1998	9	25	12	172.	10.40
1998	9	25	13	167.	12.40
1998	9	25	14	175.	12.40
1998	9	25	15	276.	8.60
1998	9	25	16	279.	7.40
1998	9	25	17	299.	10.20
1998	9	25	18	303.	7.60
1998	9	25	19	302.	7.60
1998	9	25	20	304.	8.20
1998	9	25	21	296.	9.60
1998	9	25	22	302.	11.60
1998	9	25	23	297.	13.60
1998	9	26	0	286.	13.20
1998	9	26	1	281.	13.40
1998	9	26	2	284.	12.40
1998	9	26	3	282.	15.00
1998	9	26	4	276.	14.40
1998	9	26	5	291.	16.80
1998	9	26	6	282.	16.60
1998	9	26	7	288.	16.60
1998	9	26	8	285.	18.20
1998	9	26	9	290.	18.60
1998	9	26	10	285.	16.80
1998	9	26	11	299.	17.60
1998	9	26	12	293.	16.00
1998	9	26	13	292.	13.20
1998	9	26	14	298.	7.40
1998	9	26	15	296.	7.00
1998	9	26	16	305.	4.00
1998	9	26	17	233.	1.60
1998	9	26	18	243.	2.80
1998	9	26	19	264.	.40
1998	9	26	20	155.	1.40
1998	9	26	21	106.	.40
1998	9	26	22	122.	2.40

1998	9	26	23	120.	3.60
1998	9	27	0	133.	3.60
1998	9	27	1	115.	4.40
1998	9	27	2	120.	5.60
1998	9	27	3	115.	6.40
1998	9	27	4	125.	8.80
1998	9	27	5	136.	8.00
1998	9	27	6	147.	9.20
1998	9	27	7	139.	11.00
1998	9	27	8	139.	10.80
1998	9	27	9	129.	10.20
1998	9	27	10	128.	9.00
1998	9	27	11	135.	8.80
1998	9	27	12	132.	7.80
1998	9	27	13	132.	7.20
1998	9	27	14	138.	5.00
1998	9	27	15	133.	2.40
1998	9	27	16	180.	.00
1998	9	27	17	325.	.40
1998	9	27	18	39.	.20
1998	9	27	19	27.	3.20
1998	9	27	20	41.	3.00
1998	9	27	21	35.	3.80
1998	9	27	22	10.	1.60
1998	9	27	23	28.	2.60
1998	9	28	0	7.	1.40
1998	9	28	1	333.	3.20
1998	9	28	2	299.	3.60
1998	9	28	3	266.	5.60
1998	9	28	4	246.	4.60
1998	9	28	5	234.	5.00
1998	9	28	6	328.	3.20
1998	9	28	7	320.	3.00
1998	9	28	8	313.	2.20
1998	9	28	9	329.	4.00
1998	9	28	10	350.	3.20
1998	9	28	11	270.	5.20
1998	9	28	12	275.	6.40
1998	9	28	13	266.	5.60
1998	9	28	14	294.	8.20
1998	9	28	15	305.	10.00
1998	9	28	16	303.	10.00
1998	9	28	17	296.	7.80
1998	9	28	18	304.	8.80
1998	9	28	19	295.	9.00
1998	9	28	20	304.	7.00
1998	9	28	21	308.	8.80
1998	9	28	22	308.	8.20
1998	9	28	23	299.	11.60
1998	9	29	0	304.	11.80
1998	9	29	1	319.	10.40
1998	9	29	2	298.	12.00
1998	9	29	3	314.	11.60
1998	9	29	4	300.	12.40
1998	9	29	5	302.	7.20
1998	9	29	6	288.	8.60
1998	9	29	7	278.	7.20

1998	9	29	8	284.	8.80
1998	9	29	9	296.	7.60
1998	9	29	10	252.	4.00
1998	9	29	11	256.	4.20
1998	9	29	12	268.	6.20
1998	9	29	13	243.	6.80
1998	9	29	14	264.	7.40
1998	9	29	15	259.	8.00
1998	9	29	16	258.	7.20
1998	9	29	17	269.	7.60
1998	9	29	18	282.	4.20
1998	9	29	19	283.	5.20
1998	9	29	20	291.	6.00
1998	9	29	21	267.	5.20
1998	9	29	22	290.	9.20
1998	9	29	23	290.	5.80
1998	9	30	0	302.	7.00
1998	9	30	1	299.	9.00
1998	9	30	2	322.	5.80
1998	9	30	3	302.	5.80
1998	9	30	4	287.	7.20
1998	9	30	5	328.	6.80
1998	9	30	6	345.	5.80
1998	9	30	7	290.	4.20
1998	9	30	8	302.	5.00
1998	9	30	9	16.	3.60
1998	9	30	10	78.	3.00
1998	9	30	11	115.	2.60
1998	9	30	12	152.	3.80
1998	9	30	13	161.	4.40
1998	9	30	14	145.	4.80
1998	9	30	15	217.	3.00
1998	9	30	16	277.	6.80
1998	9	30	17	264.	5.80
1998	9	30	18	304.	1.20
1998	9	30	19	249.	5.40
1998	9	30	20	234.	4.40
1998	9	30	21	210.	2.20
1998	9	30	22	190.	1.00
1998	9	30	23	261.	8.80
1998	10	1	0	266.	6.60
1998	10	1	1	243.	4.20
1998	10	1	2	280.	6.60
1998	10	1	3	270.	4.60
1998	10	1	4	282.	6.20
1998	10	1	5	264.	2.80
1998	10	1	6	243.	7.20
1998	10	1	7	224.	4.60
1998	10	1	8	231.	6.80
1998	10	1	9	236.	8.40
1998	10	1	10	239.	3.40
1998	10	1	11	266.	5.20
1998	10	1	12	269.	6.80
1998	10	1	13	279.	6.40
1998	10	1	14	273.	7.00
1998	10	1	15	257.	4.60
1998	10	1	16	288.	6.20

1998	10	1	17	305.	9.40
1998	10	1	18	297.	12.20
1998	10	1	19	314.	11.60
1998	10	1	20	295.	11.00
1998	10	1	21	292.	12.80
1998	10	1	22	294.	13.00
1998	10	1	23	291.	13.40
1998	10	2	0	303.	13.20
1998	10	2	1	300.	8.20
1998	10	2	2	292.	9.80
1998	10	2	3	311.	10.60
1998	10	2	4	316.	6.00
1998	10	2	5	346.	1.40
1998	10	2	6	298.	1.80
1998	10	2	7	245.	5.00
1998	10	2	8	291.	11.40
1998	10	2	9	310.	10.20
1998	10	2	10	317.	13.40
1998	10	2	11	304.	15.40
1998	10	2	12	297.	12.40
1998	10	2	13	298.	13.20
1998	10	2	14	305.	16.60
1998	10	2	15	302.	17.40
1998	10	2	16	301.	17.40
1998	10	2	17	290.	17.00
1998	10	2	18	292.	17.40
1998	10	2	20	298.	20.40
1998	10	2	21	302.	20.60
1998	10	2	22	304.	19.40
1998	10	2	23	303.	18.40
1998	10	3	0	302.	19.20
1998	10	3	1	306.	18.00
1998	10	3	2	302.	19.00
1998	10	3	3	307.	18.40
1998	10	3	4	310.	17.40
1998	10	3	6	311.	15.00
1998	10	3	7	301.	16.60
1998	10	3	8	296.	16.00
1998	10	3	9	299.	15.00
1998	10	3	10	296.	16.20
1998	10	3	11	298.	15.20
1998	10	3	12	291.	16.00
1998	10	3	13	291.	16.60
1998	10	3	14	292.	17.00
1998	10	3	15	301.	16.80
1998	10	3	16	298.	18.20
1998	10	3	17	297.	15.60
1998	10	3	18	299.	15.60
1998	10	3	19	297.	14.00
1998	10	3	20	302.	14.60
1998	10	3	21	306.	12.60
1998	10	3	22	312.	16.00
1998	10	3	23	301.	16.80
1998	10	4	0	308.	13.00
1998	10	4	1	306.	12.20
1998	10	4	2	307.	11.20
1998	10	4	3	312.	12.00

1998	10	4	4	326.	10.60
1998	10	4	5	340.	9.80
1998	10	4	6	336.	10.60
1998	10	4	7	329.	11.60
1998	10	4	8	335.	10.20
1998	10	4	9	321.	11.60
1998	10	4	10	325.	10.80
1998	10	4	11	322.	11.00
1998	10	4	12	322.	14.20
1998	10	4	13	316.	13.00
1998	10	4	14	312.	12.60
1998	10	4	15	318.	13.20
1998	10	4	16	315.	13.60
1998	10	4	17	311.	18.20
1998	10	4	18	308.	16.40
1998	10	4	19	305.	14.60
1998	10	4	20	317.	13.60
1998	10	4	21	335.	10.80
1998	10	4	22	333.	8.20
1998	10	4	23	323.	7.40
1998	10	5	0	317.	7.40
1998	10	5	1	319.	8.40
1998	10	5	2	331.	8.60
1998	10	5	3	325.	9.20
1998	10	5	4	319.	9.80
1998	10	5	5	342.	8.00
1998	10	5	6	330.	5.20
1998	10	5	7	335.	4.40
1998	10	5	8	322.	3.40
1998	10	5	9	314.	3.00
1998	10	5	10	291.	2.60
1998	10	5	11	335.	2.80
1998	10	5	12	306.	6.80
1998	10	5	13	318.	10.20
1998	10	5	14	296.	7.00
1998	10	5	15	302.	8.60
1998	10	5	16	318.	8.60
1998	10	5	17	331.	11.80
1998	10	5	18	339.	10.20
1998	10	5	19	350.	8.60
1998	10	5	20	21.	5.80
1998	10	5	21	352.	3.80
1998	10	5	22	319.	4.00
1998	10	5	23	35.	4.40
1998	10	6	0	99.	4.40
1998	10	6	1	124.	4.40
1998	10	6	2	90.	4.80
1998	10	6	3	115.	6.20
1998	10	6	4	98.	4.20
1998	10	6	5	155.	3.20
1998	10	6	6	184.	2.80
1998	10	6	7	202.	4.80
1998	10	6	8	192.	6.20
1998	10	6	9	152.	5.40
1998	10	6	10	138.	8.00
1998	10	6	11	142.	4.20
1998	10	6	12	159.	2.00

1998	10	6	13	133.	.40
1998	10	6	14	62.	2.80
1998	10	6	15	104.	2.00
1998	10	6	16	180.	1.20
1998	10	6	17	255.	2.20
1998	10	6	18	73.	4.80
1998	10	6	19	94.	6.00
1998	10	6	20	154.	3.00
1998	10	6	21	247.	8.40
1998	10	6	22	246.	3.80
1998	10	6	23	201.	3.40
1998	10	7	0	188.	.20
1998	10	7	1	6.	.80
1998	10	7	2	77.	3.00
1998	10	7	3	218.	3.20
1998	10	7	4	262.	2.60
1998	10	7	5	42.	.20
1998	10	7	6	236.	1.00
1998	10	7	7	215.	4.40
1998	10	7	8	90.	4.20
1998	10	7	9	106.	5.00
1998	10	7	10	90.	1.00
1998	10	7	11	95.	2.80
1998	10	7	12	137.	4.00
1998	10	7	13	154.	3.60
1998	10	7	14	154.	3.60
1998	10	7	15	136.	3.80
1998	10	7	16	167.	4.80
1998	10	7	17	183.	5.20
1998	10	7	18	173.	5.00
1998	10	7	19	175.	5.20
1998	10	7	20	176.	4.40
1998	10	7	21	157.	4.80
1998	10	7	22	168.	4.60
1998	10	7	23	174.	3.20
1998	10	8	0	164.	1.20
1998	10	8	1	119.	6.60
1998	10	8	2	125.	7.40
1998	10	8	3	209.	6.40
1998	10	8	4	204.	3.20
1998	10	8	5	262.	4.60
1998	10	8	6	273.	6.80
1998	10	8	7	293.	10.80
1998	10	8	8	300.	9.00
1998	10	8	9	317.	8.20
1998	10	8	10	313.	8.00
1998	10	8	11	311.	11.40
1998	10	8	12	308.	14.60
1998	10	8	13	312.	15.20
1998	10	8	14	308.	11.40
1998	10	8	15	303.	15.20
1998	10	8	16	306.	13.40
1998	10	8	17	299.	13.00
1998	10	8	18	301.	18.20
1998	10	8	19	302.	18.00
1998	10	8	20	304.	18.60
1998	10	8	21	304.	20.80

1998	10	8	22	304.	20.20
1998	10	8	23	308.	20.20
1998	10	9	0	310.	19.80
1998	10	9	1	311.	19.20
1998	10	9	2	312.	17.80
1998	10	9	3	313.	18.00
1998	10	9	4	308.	19.40
1998	10	9	5	313.	18.40
1998	10	9	6	312.	16.60
1998	10	9	7	304.	17.60
1998	10	9	8	307.	17.00
1998	10	9	9	305.	16.60
1998	10	9	11	304.	14.40
1998	10	9	12	295.	14.20
1998	10	9	13	293.	13.40
1998	10	9	14	292.	15.40
1998	10	9	15	289.	17.80
1998	10	9	16	298.	16.20
1998	10	9	17	295.	16.60
1998	10	9	18	308.	19.60
1998	10	9	19	309.	21.40
1998	10	9	20	315.	20.00
1998	10	9	21	314.	20.20
1998	10	9	23	305.	21.40
1998	10	10	0	306.	22.00
1998	10	10	1	313.	21.00
1998	10	10	2	312.	21.40
1998	10	10	3	309.	21.00
1998	10	10	4	313.	18.00
1998	10	10	5	316.	18.40
1998	10	10	6	317.	17.00
1998	10	10	7	316.	18.40
1998	10	10	8	318.	16.80
1998	10	10	9	323.	15.40
1998	10	10	10	320.	12.80
1998	10	10	11	315.	13.80
1998	10	10	12	323.	12.60
1998	10	10	13	320.	14.20
1998	10	10	14	310.	17.60
1998	10	10	15	315.	18.20
1998	10	10	16	320.	17.80
1998	10	10	17	312.	18.20
1998	10	10	18	308.	19.40
1998	10	10	19	312.	18.80
1998	10	10	20	313.	15.80
1998	10	10	21	308.	15.60
1998	10	10	22	307.	14.60
1998	10	10	23	311.	12.20

Appendix B

```
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*
 Scenario Specification: 3-D FULL FATES Model
*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*-*

 Scenario Name : CMND1OV2
 Description   : Wind, background currents

 Oil Spilled   : No. 6 fuel
 Amount Spilled :      3000.00 gallons        =        10.82 Metric Tons

 Spill Location along Command trackline near:
 Longitude (deg., min.): 122  41.4345 (W) =122.69060 (W)
 Latitude  (deg., min.):  37  35.3618 (N) = 37.58936 (N)

 Spill Starts (Yr, Mo, Day, Hr) :  1998  Sep. 26   21:00
 Release Duration (hrs)          :     .0
                  (instantaneous release)

 Simulation Time Step Fixed (hrs) :   1.00000
 Length of the Simulation (days)  :  10.0

 Number of Sublots (Lagrangian particles) Simulated:
   Number of Spillets              :   100
   Number of Aromatic Particles    :   500
   Number of Oil Droplet Particles:    250

  2 Windfile(s) Used:
      46012PST.WNE
      46026PST.WNE
 Surface Oil wind drift factor:   3.5 %
 Surface Oil wind drift angle :    .0 deg.

 Current file         : COMND1.DIR
 Type of current data: 2-D, rectilinear grid
                        Static background currents
              Tidal currents

 Habitat Grid File: SANMAT1.GRD
 Fetch: calculated from grid if = 0, or in km:
   from N:          .00 km
   from E:          .00 km
   from S:          .00 km
   from W:      5000.00 km

 Horizontal Turbulent Dispersion Coefficient:  1.00 m2/sec
 Constant Vertical Turbulent Dispersion Coefficient: .001000 (m**2/sec)

 Air Temperature (deg.C)    :   14.
 Water Temperature (deg.C) :   14.
 Salinity (ppt)             :  32.0
   This salinity is assumed constant in space.
   Density is calculated from salinity and temperature.

 Suspended Sediment Concentration (mg/l): 10.00
 Suspended Sediment Settling Velocity (m/day)  :  3.00

 Droplets Contacting Bottom Sediments and Shorelines Do Not Stick.

 Surface release assumed
```

Properties Assumed for: No. 6 fuel

Density @ 25 deg. C (g/cm3)	:	.953000
Viscosity @ 25 deg. C (cp)	:	3180.000000
Surface Tension (dyne/cm)	:	40.000000
Pour Point (deg. C)	:	15.0
Initial Boiling Pt. (deg. C)	:	400.0
Aromatic Particulate/Dissolved	:	1402.000000
Adsorption Rate to Susp. Sedmnt	:	.010080
Adsorption Salinity Coef.(/ppt)	:	.023000
Fraction Low Mol.Wt. Aromatics	:	.0000
Fraction High Mol.Wt. Aromatics	:	.0310
Fraction Non-Aromatic Volatiles	:	.0460
A1-- Intercept Henry`s Law v. T	:	27.500000
B1-- Slope Henry`s Law v. T	:	22.066000
To-- Init. Boiling Pt.(deg. K)	:	582.300000
Tg--Gradient Distillation Curve	:	141.510000
Minimum Oil Thickness (m)	:	.000010
Maximum Mousse Water Content (%)	:	70.00
Degradation Rate (/day), Surface & Shore	:	.010000
Degradation Rate (/day), Oil in Water	:	.010000
Degradation Rate (/day), Oil in Sediment	:	.001000
Degradation Rate (/day), Arom. in Water	:	.040000
Degradation Rate (/day), Arom. Sediment	:	.004000

Appendix C

Trajectory Model Output

The following figures show the surface trajectory of the oil. The date and time are in the upper left corner of each figure. The black dots represent the centers of individual slicks ("spillets") at each time. Oil coming ashore is displayed as a red dot on the shoreline. The polygons are the oil slick observations. Refer to Figure 3-1 for the times of those observations. Figure 3-1 is repeated below for convenience.

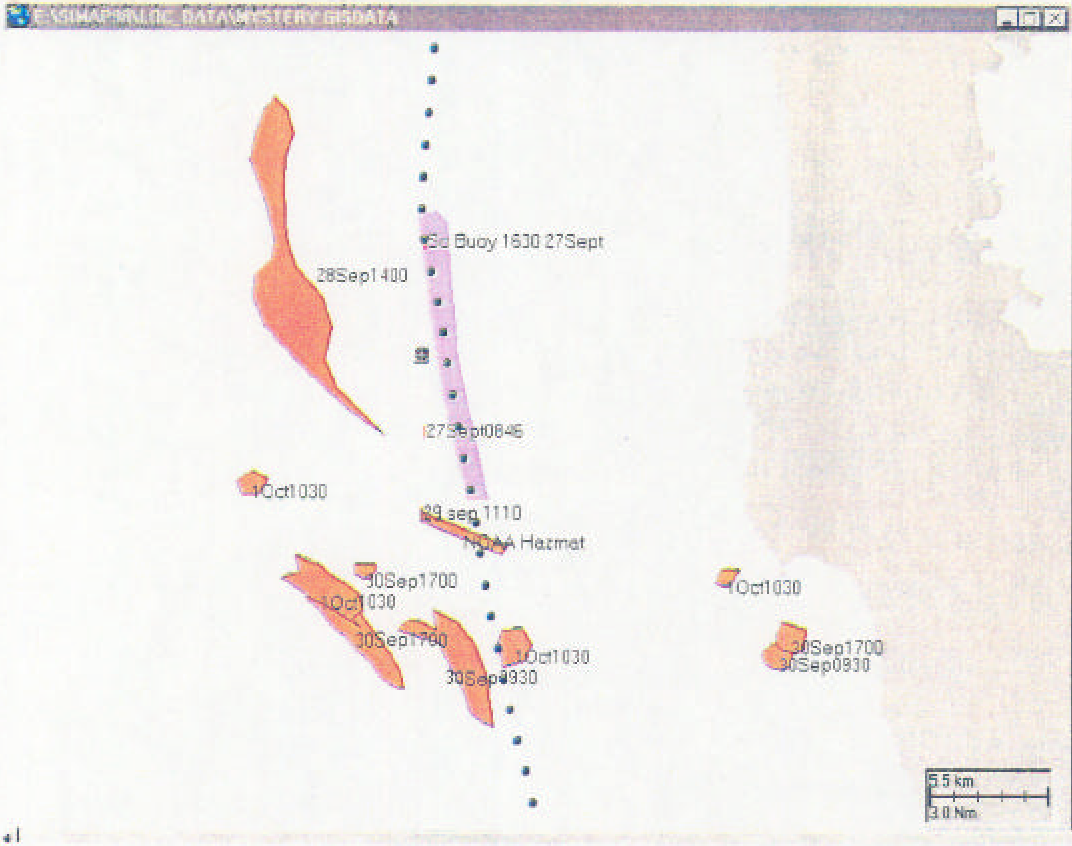
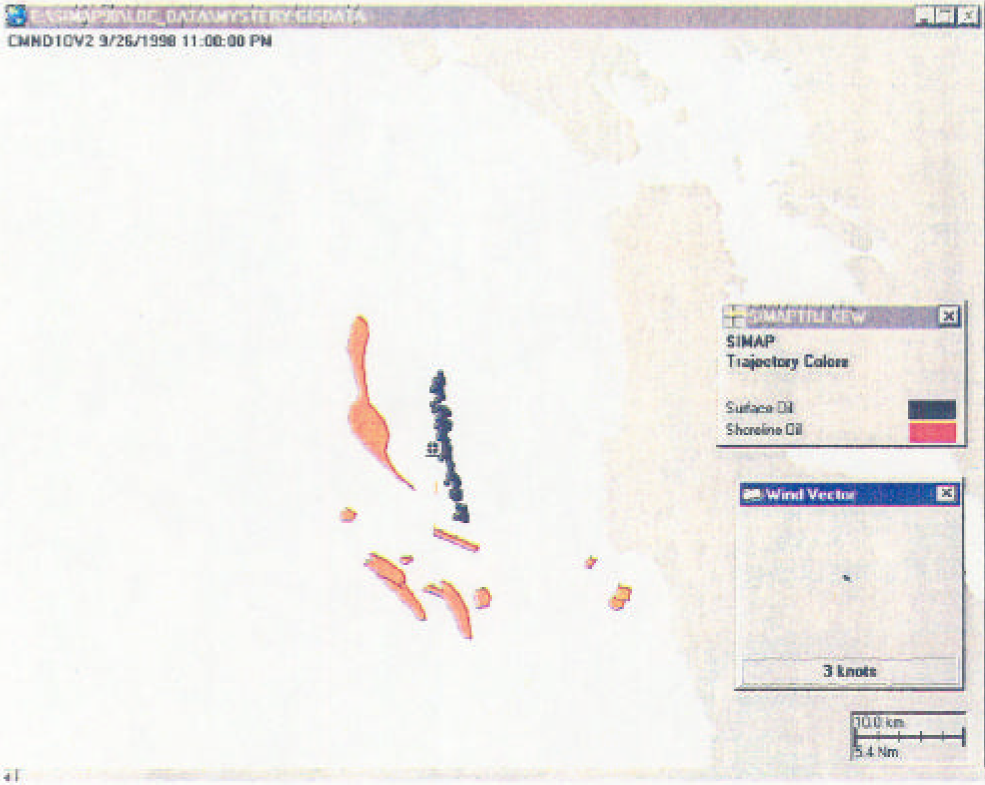
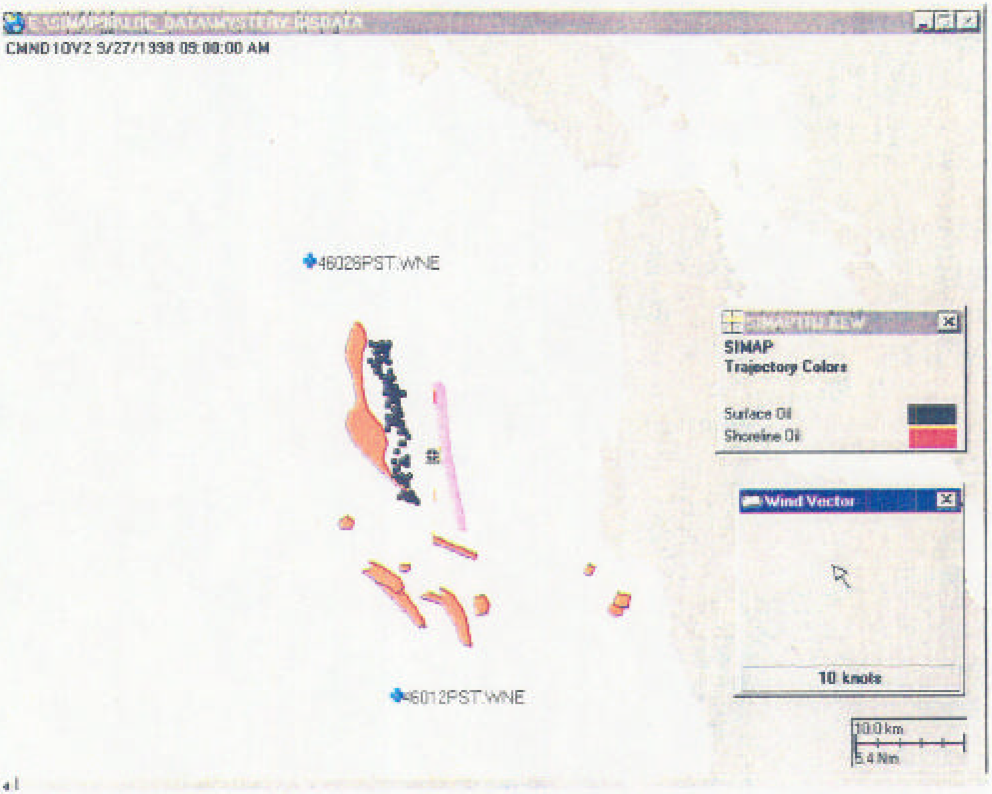


Figure 3-1. Oil slicks observed from 27 September to 1 October, 1998k. The dots represent the track line of the Command. The shaded section of the track line is the assumed location of the release.

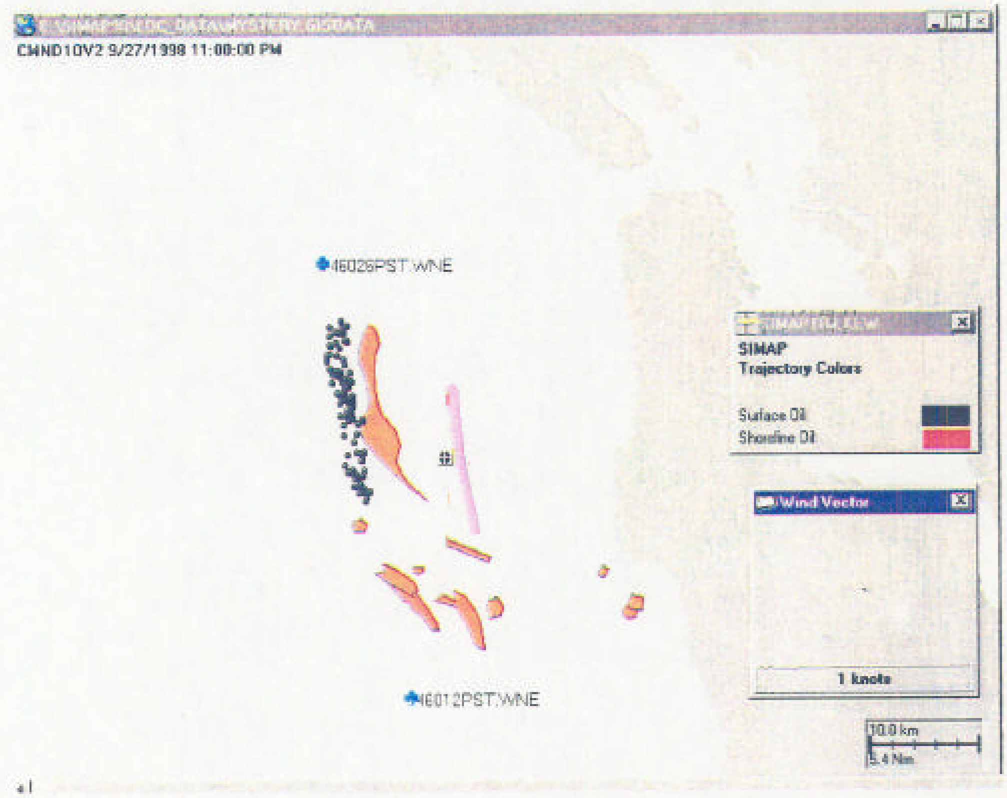


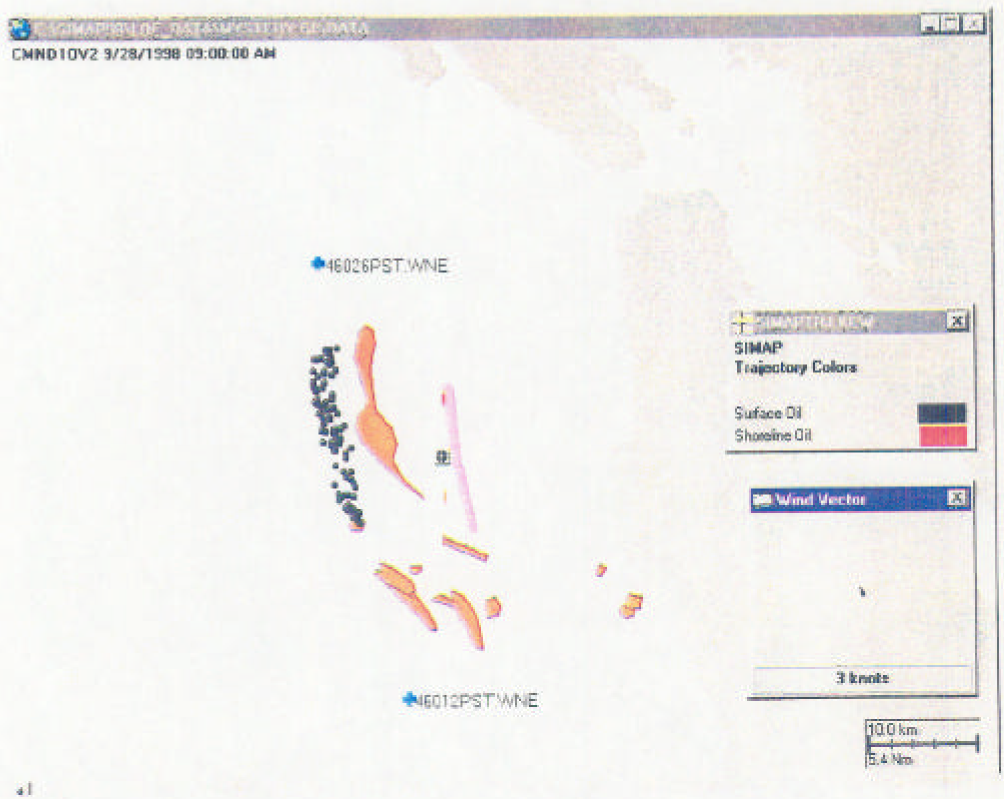
CMND10V2 9/26/1998 11:00:00 PM
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
3 knots
10.0 km
5.4 Nm

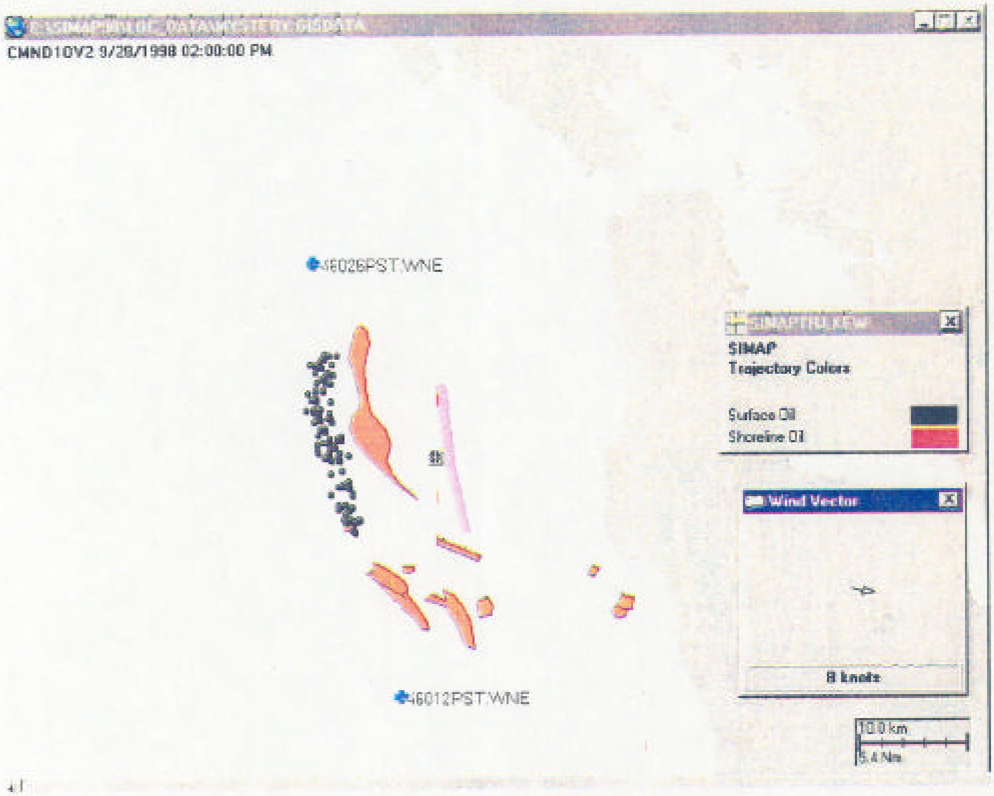
CMND10V2 9/27/1998 06:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
8 knots
46012PST.WNE
10.0 km
5.4 Nm


CMND10V2 9/27/1998 09:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
10 knots
46012PST.WNE
10.0 km
5.4 Nm

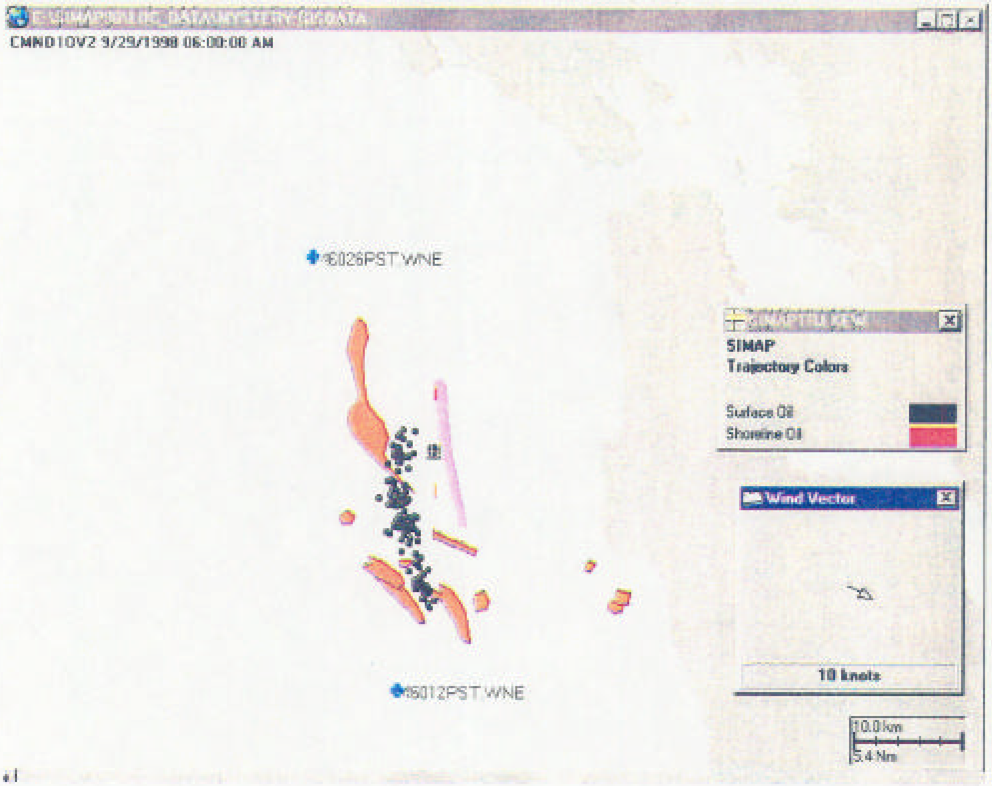

CMND10V2 9/27/1998 04:00:00 PM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
4 knots
46012PST.WNE
10.0 km
5.4 Nm


CMND10V2 9/27/1998 11:00:00 PM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
1 knots
46012PST.WNE
10.0 km
5.4 Nm


CMND10V2 9/28/1998 09:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
3 knots
46012PST.WNE
10.0 km
5.4 Nm

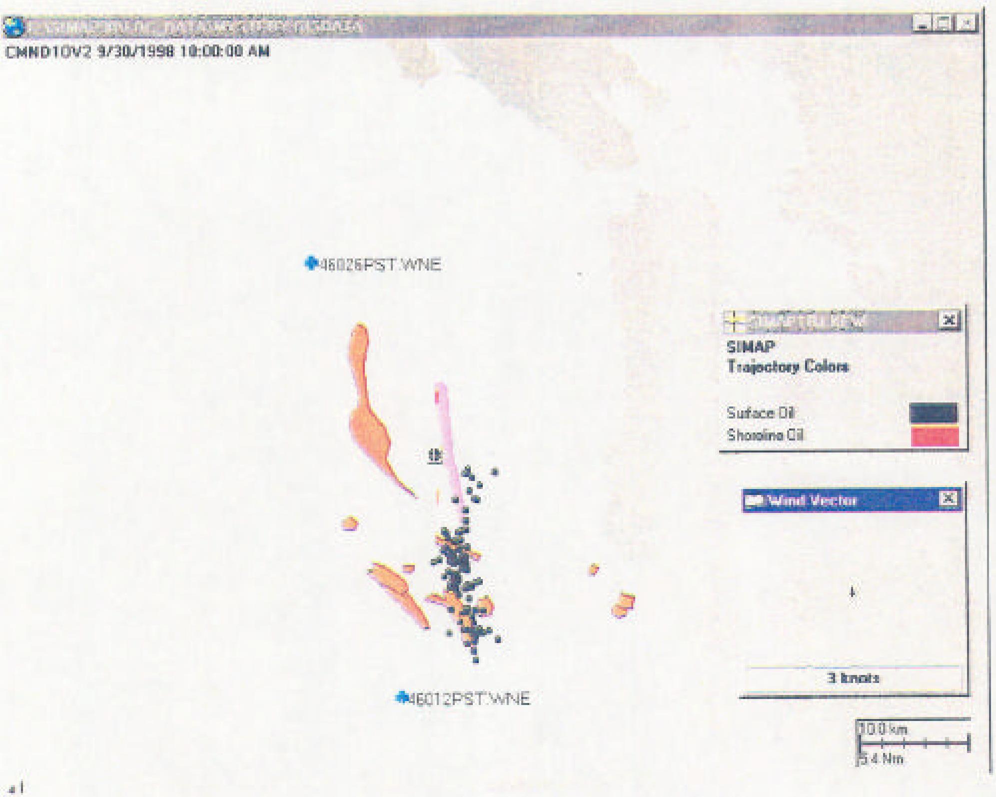

CMND10V2 9/29/1998 02:00:00 PM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
8 knots
46012PST.WNE
10.0 km
5.4 Nm

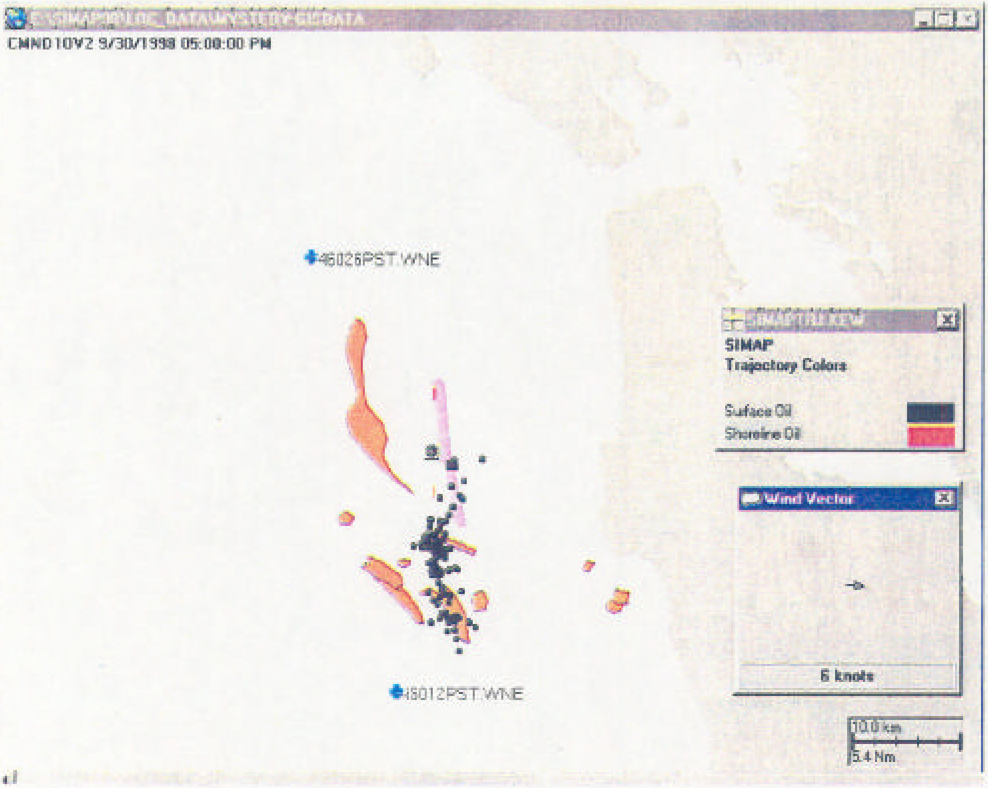

CMND10V2 9/29/1998 00:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
14 knots
46012PST.WNE
10.0 km
5.4 Nm

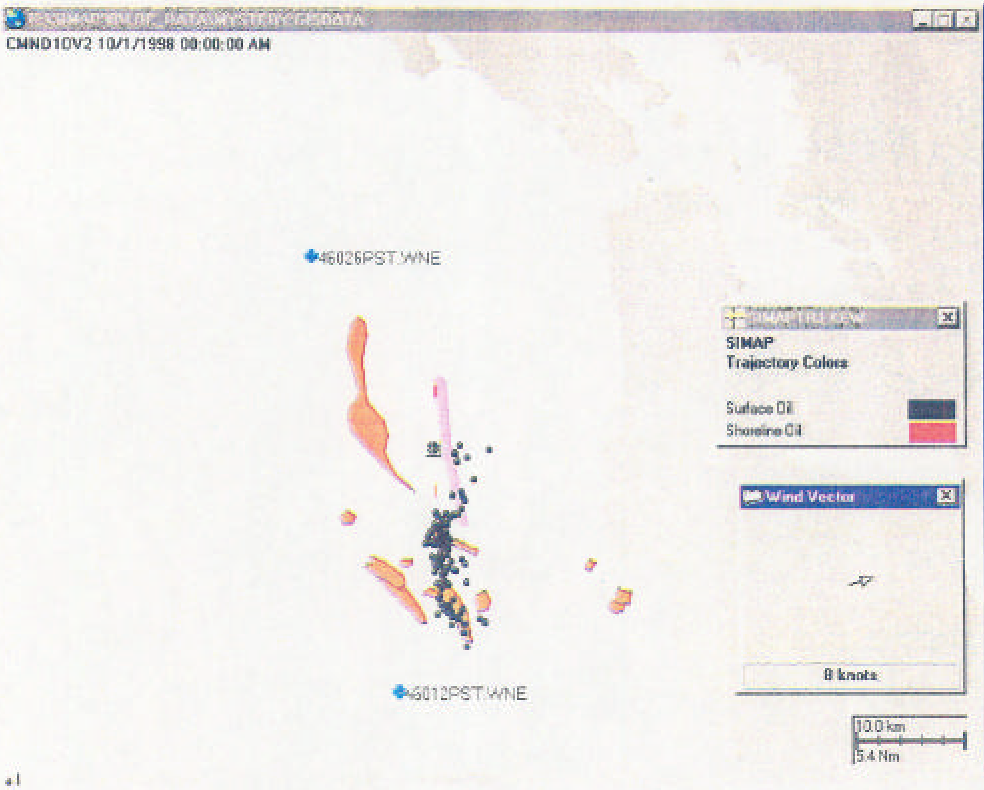

CMND10V2 9/29/1998 06:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
10 knots
46012PST.WNE
10.0 km
5.4 Nm


CMND10V2 9/29/1998 11:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
4 knots
46012PST.WNE
10.0 km
5.4 Nm


CMND1OV2 9/30/1998 00:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
7 knots
46012PST.WNE
10.0 km
5.4 Nm

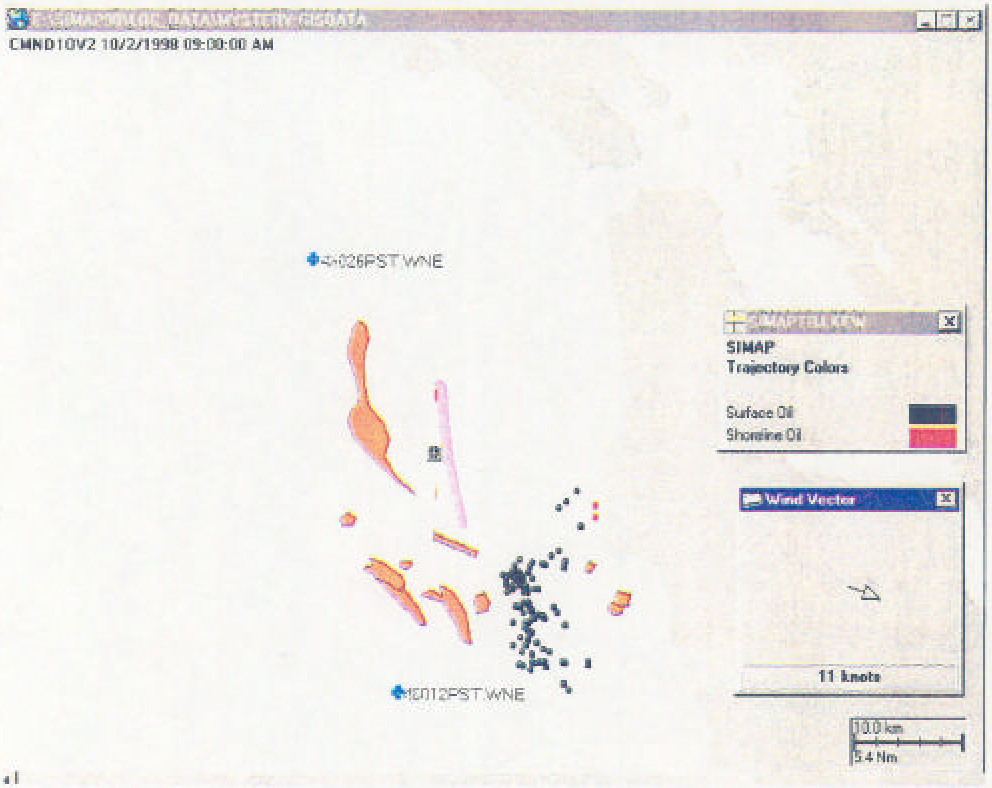

CMND1OV2 9/30/1998 10:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
3 knots
46012PST.WNE
10.0 km
5.4 Nm


CMND10V2 9/30/1998 05:00:00 PM
46026PST.WNE
46012PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
6 knots
10.0 km
5.4 Nm

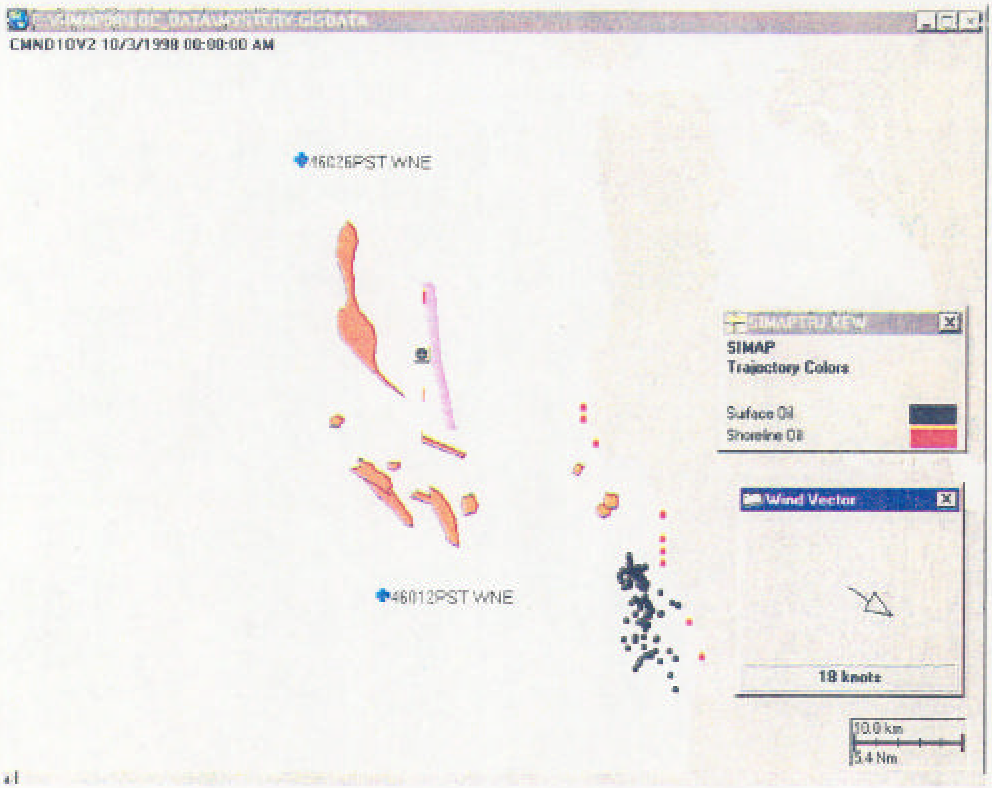

CMND10V2 10/1/1998 00:00:00 AM
46026PST.WNE
46012PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
8 knots
10.0 km
5.4 Nm


CMND1OV2 10/1/1998 11:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
4 knots
46012PST.WNE
10.0 km
5.4 Nm

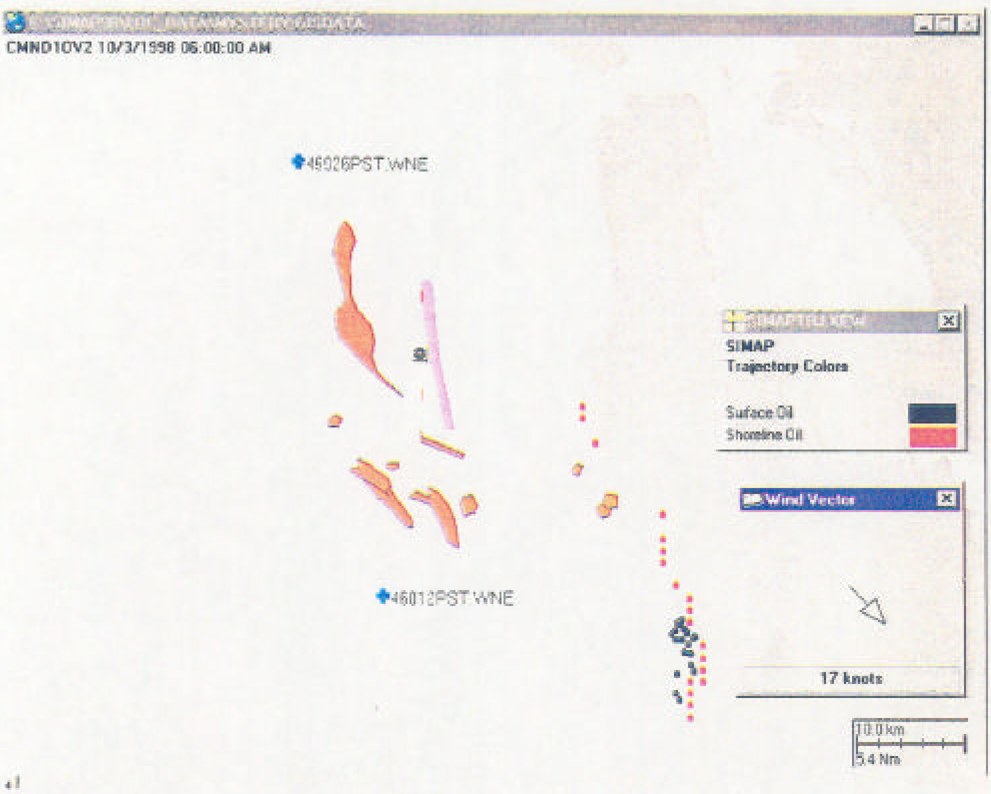

CMND1OV2 10/2/1998 00:00:00 AM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
14 knots
46012PST.WNE
10.0 km
5.4 Nm


CMND1OV2 10/2/1998 09:00:00 AM
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
11 knots
10.0 km
5.4 Nm


CMND1OV2 10/2/1998 06:00:00 PM
46026PST.WNE
SIMAP
Trajectory Colors
Surface Oil
Shoreline Oil
Wind Vector
17 knots
10.0 km
5.4 Nm



CMND1OV2 10/3/1998 00:00:00 AM
46026PST WNE
46012PST WNE
SIMAP
Trajectory Colors
Suface Oil
Shoreline Oil
Wind Vector
18 knots
10.0 km
5.4 Nm



CMND1OV2 10/3/1998 06:00:00 AM
46026PST WNE
46012PST WNE
SIMAP
Trajectory Colors
Suface Oil
Shoreline Oil
Wind Vector
17 knots
10.0 km
5.4 Nm